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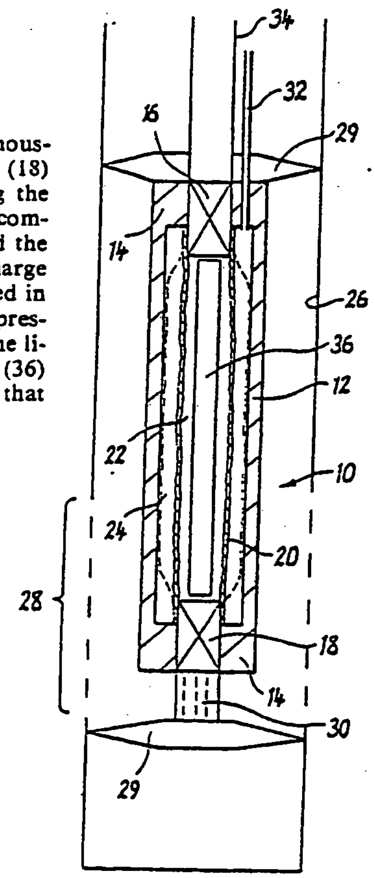
(54) Title: FLUID OPERATED DIAPHRAGM PUMP

(57) Abstract

A liquid handling device (10) having: a housing (12) defining a chamber and housing an inlet and an outlet; a non-return valve of at least one of the inlet and outlet (18) (16); and a flexible tubular diaphragm (20) within the housing (12) and dividing the chamber into two compartments (24), (22), one of the compartments (the discharge compartment) (22) providing communication between the inlet (18) and outlet (16) and the other compartment (24) (the pressurizing compartment) extending around the discharge compartment, with the arrangement being such that with a quantity of liquid received in the discharge compartment (22) via the inlet (18), an increase of fluid pressure in the pressurizing compartment (24) causes the diaphragm (20) to be contracted to discharge the liquid in compartment (22) through outlet (16); the device further including means (36) within the compartment (22) to limit construction of the diaphragm (20) to an extent that communication is maintained between the inlet and outlet during discharge.



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FLUID OPERATED DIAPHRAGM PUMP

This invention relates to a liquid handling device. The device of the invention has particular application to the sampling of bore water although, as will hereinafter become apparent, the device has other applications.

There are inherent difficulties in sampling bore water, particularly in a multiple aquifer system where each aquifer is itself divided or multilayered. Horizontal stratification of an aquifer and varying vertical and horizontal hydraulic conductivities of individual aquifers may be reflected by vertical changes in water quality. A sampling device which interferes with the natural situation, such as by resulting in mixing of water from different levels clearly is of limited value.

There previously has been proposed a device intended for use at a pump. The device has an elongate housing and a tubular diaphragm or membrane (hereinafter referred to as a diaphragm) extending longitudinally in the housing between inlet and outlet ports. Liquid taken into the diaphragm through a one-way valve at the inlet port is intended then to be pumped from the device, via a further one-way valve at the outlet, by pressurized fluid charged to the housing exteriorly of the diaphragm.

In use, this cycle is intended to be repeated to pump successive charges of liquid. However, it is found that while the discharge of liquid from such device can operate efficiently, the intake of further liquid is substantially prevented. This is due to the diaphragm collapsing adjacent the outlet to prevent discharge of liquid, or collapsing completely on completion of the discharge and, as a result, resisting expansion to its original volume because of the vacuum existing within the diaphragm. Such device therefore is not known to have ever been adopted to any practical extent.

The present invention seeks to provide an improved form of such liquid handling device suitable for use in sampling bore water by causing minimal interference to the natural situation or condition of the liquid being sampled, while overcoming such deficiency in operation.

The invention provides a liquid handling device having: a housing defining a chamber and having an inlet and

an outlet; a non-return valve at at least one of the inlet and outlet; and a flexible tubular diaphragm within the housing and dividing the chamber into two compartments, one of the compartments (the discharge compartment) providing communication between the inlet and the outlet and the other of the compartments (the pressurizing compartment) extending around the discharge compartment with the arrangement being such that with a quantity of liquid received in the discharge compartment via the inlet, an increase of fluid pressure in the pressurizing compartment causes the diaphragm to be constricted to discharge the liquid in the discharge compartment through the outlet; the device further including means within the discharge compartment to limit constriction of the diaphragm to an extent that communication is maintained between the inlet and outlet during discharge.

The means for limiting constriction of the diaphragm can take a variety of forms, and preferably is such as to prevent formation of a vacuum therein. In a first form, it can be a support member extending within the discharge compartment and separate from the diaphragm. In a second form, it can consist of a configured inner surface of the diaphragm.

In the first, support member form for the means for limiting constriction, the support member can consist of a physical obstruction preventing substantially complete constriction of the diaphragm. The support member preferably acts so that the discharge compartment retains communication between the inlet and outlet substantially throughout the length of the diaphragm, even when the latter is constricted. Suitable support members include those of cruciform or, for example, three- or five-arm star-shaped cross-section. Alternatively, the support member may be tubular and have a polygonal cross-section, such as triangular, square, rectangular, pentagonal or hexagonal cross-section; or the support member can be tubular with a circular or elliptical cross-section, or it may be in the form of a rod of such cross-sections.

In the second configured surface form of the means for limiting constriction, the inner surface of the diaphragm can have protrusions extending into the discharge compartment which similarly prevent substantially complete

constriction of the diaphragm. Again, the purpose is to retain communication between the inlet and outlet, even when the diaphragm is fully constricted to the extent permitted by the protrusions. Thus, the inner surface may be provided with ribs which extend circumferentially, longitudinally or helically of the discharge compartment. Alternatively, there may be formed over the inner surface of the diaphragm an array of pimple-like projections extending thereover. In each case, the configured inner surface acts to arrest constriction of the diaphragm due to interference with opposed portions of the configured surface so that the inlet and outlet remain in communication.

In the support member form, that member can be of any suitable material able to withstand forces applied thereto during constriction of the diaphragm to discharge liquid from the discharge compartment, via the outlet. It also is highly desirable that the material be substantially inert to the liquid to pass through the discharge compartment. A wide variety of plastics materials or metals are suitable for these purposes.

With use of a support member, a number of additional benefits can be derived in that it can be used to remove entrained solids or soluble compounds in the liquid to pass through the discharge compartment. Thus, the support member may have a suitable filter material, such as by being formed of, or having therein, such filter material. In one arrangement, the support member may be a porous rod of diatomaceous earth, alumina, activated carbon or other suitable filter material; if need be, with a perforate sleeve thereon to increase strength. In such case, the support member is able to filter out entrained solids, and even some dissolved compounds from the liquid to pass through the one compartment. Alternatively, with a tubular support member, that member may include a sleeve thereon formed of a membrane material suitable for separating dissolved compounds, by reverse osmosis or by ion-exchange, from the liquid passing through the discharge compartment. In the latter case, the tubular component of the support member provides a support for its membrane sleeve in addition to providing a support limiting

constriction of the diaphragm. Also, in a still further alternative using a tubular support member, the latter may be filled with beads of an ion-exchange resin material for such removal of dissolved compounds.

In such alternatives enabling filtering of entrained solids, or of dissolved compounds, communication between the inlet and outlet to the discharge compartment may necessitate the support member terminating short of the inlet, but extending to the outlet. Thus, liquid passing through the discharge compartment may be received from the inlet into a portion of the discharge compartment extending around the support member, and from that portion into the portion occupied by the support member for flow in the latter to the outlet. That is, on constriction of the membrane dividing the housing chamber, by increase in fluid pressure in the pressurizing compartment, the liquid in the discharge compartment is forced to pass into the support member and, from the latter to the outlet.

Where the support member is of tubular form and has a reverse osmosis or ion-exchange membrane sleeve thereon, or ion-exchange beads therein, the tubular form preferably is characterized by a perforate circumferential surface. The end of the tubular form nearest the inlet may be closed by an imperforate end wall, or by such sleeve membrane where the latter is present. However, where the tubular form is filled with ion-exchange beads, the end nearest the inlet can be opened.

Most conveniently, the device is of elongate form, preferably cylindrical. In that form, the device may be of quite small transverse section such that, when used for sampling bore water, it can readily be inserted to a required depth in a narrow test bore. Such device can be of a transverse section enabling it to be inserted into quite small test bores of 50 mm. diameter or even less although, as will be appreciated, the length of the device may need to be substantial compared to its transverse dimensions to enable a practical sample quantity to be discharged.

Particularly where the device is for use in obtaining bore water samples, or even a bore water supply, an increase

in fluid pressure in the pressurizing compartment typically requires charging of the fluid from the head of the bore, i.e. from a location remote from the housing. For such purpose, the device includes at least one fluid supply conduit providing communication between a source of pressurized fluid at that location and the pressurizing compartment. Also, to enable pulsed pressurization of the discharge compartment, followed by its depressurization to enable refilling of the discharge compartment with liquid, the device most conveniently includes a control valving means enabling the charging of fluid from the source to, followed by discharging of fluid from, the pressurizing compartment. The discharging of fluid from the pressurizing compartment can be via the at least one supply conduit or via a discharge conduit; while such discharging can be vacuum or pump assisted.

Where the device is of elongate form, the inlet and outlet may be at respective ends of the housing. In such case, the diaphragm may have a respective end secured at the inlet and outlet end of the housing. Most conveniently, a respective non-return or one-way valve is provided at each of the inlet and outlet; the valve at the inlet permitting the flow of liquid to be pumped to be received only into the discharge compartment, while the valve at the outlet permitting only discharge of the liquid from that compartment.

The device is suitable for obtaining samples from any required depth in a bore hole although, as will be appreciated, the housing and valves must be able to withstand pressure prevailing at a particular depth at which it is to be used. Location of the device at a required depth can be ascertained by any suitable means, such as a calibrated line by which the device is raised or lowered or by a line measuring device.

It has been found that, in some down hole applications, linearity can not be relied on and that, in such cases, a device having a flexible housing can be used to advantage. Thus, while it normally is desirable to have the device housing formed of a rigid material, the housing may be non-rigid so as to permit bending of the device when inserted along a non-linear bore hole, conduit, duct or pipe.

For a substantially rigid form, the housing can be formed of a metal, or of a plastics material, such as PVC, polyethylene, polypropylene and other plastics materials, or natural or synthetic rubbers, which do not permit or are reinforced to prevent bending. However, where bending is required, the housing can be formed of flexible grades of the same plastics which allow bending of the device when inserted endwise into a non-linear bore hole or the like. In one form, the housing is of a bendable form enabling it to withstand internal pressurization without expanding. Thus, where the material of construction for the housing is such that the housing would be inflated by such pressurization, inflation may be substantially prevented by suitable internal or external reinforcement of the housing. For example, the housing may have embedded therein or extending around its outer surface, circumferential reinforcement in the form of a plurality of longitudinally spaced rings or reinforcement of helical form. The reinforcement may be of metal, such as wire, or a suitable plastics material such as nylon thread.

In an alternative bendable form, the housing may be inflatable with internal pressurization so as to increase its volume from that necessary for insertion into a bore hole to at least that limited by the bore hole. In such form, reinforcement is not necessary; although reinforcement adapted to limit inflation to an acceptable level can be provided. The reinforcement may be a relatively loosely fitting helix of wire, nylon or the like surrounding the housing. Alternatively, the reinforcement may be penannular resilient members of plastics or metal, each surrounding the housing and, if required, located in a respective one of a series of circumferential grooves spaced longitudinally along the outer surface of the housing.

It will be appreciated that where the housing is to be bendable, a rigid support member for limiting construction of the diaphragm can not be used. However, a bendable support member can be used. Also, instead of a support member, the inner surface of the diaphragm can be configured to limit diaphragm constriction.

In use, the device normally is required to pump a volume of liquid greater than that produced by a single intake and discharge of discharge compartment. Thus, after discharge of single intake, the cycle is repeated until the required volume is provided.

The fluid for use in the pressurizing compartment may be a gas, preferably air, or a liquid. The supply for this may be operable to provide pulsed operation of the pressurizing compartment timed to provide re-pressurization at the completion of filling of the discharge compartment with the liquid being pumped. Where the liquid being pumped is received at the inlet at a sufficient pressure, the pressurized fluid supply may be operable to enable the liquid being pumped, when filling the discharge compartment, to displace the fliud from the pressurizing compartment by flexing of the diaphragm on inflation by the liquid. However, an alternative arrangement is to have the pressurizing compartment in selective communication with a vacuum or reduced pressure source such that pressurized fluid charged to the pressurizing compartment, for discharge of liquid from the discharge compartment in one cycle, is drawn from the pressurizing compartment so as to aid or positively induce the filling of the discharge compartment with liquid to be pumped in the next cycle. The pressurizing compartment of the device may be connected to such vacuum or reduced pressure source via a further conduit communicating with the pressure compartment through a further port in the housing. Alternatively, the conduit providing the source of pressurized fluid may be switchable, by suitable valve means, between the source of pressurized fluid and the vacuum or reduced pressure.

A modified form of the device can be provided where concurrent pumping is required to be performed at different levels in a single bore hole. In this form, the device is of annular construction, with the housing having inner and outer peripheral walls, with the inner wall defining a passage through the device, and the flexible diaphragm or membrane extending around that inner wall. The discharge compartment thus is in the form of an annulus within the pressurizing compartment; while the means for preventing formation of a vacuum preferably

is either the above-mentioned configured surface of the diaphragm or a similar configured outer surface of the inner wall of the housing.

Such modified form of the device can be operated at the upper one of two levels at which concurrent sampling is to be conducted. Due to the provision of a bore through the device, conduits to a second device to be operated at a lower level can pass through the bore passage through the upper device, with the arrangement permitting independent adjustment of the level of the two devices. Subject to the constraint of bore hole and conduit diameters, at least a third device can be similarly operated concurrently if the second device also is of annular form.

Where the device is to be used in a bore hole, it may have means for engaging the wall of the bore hole to limit the vertical extent of strata from which liquid is receivable. The engaging means preferably comprises an upper and lower resilient packer or flange members which extend laterally beyond the periphery of the housing to resiliently engage and seal around the wall of the bore hole. Such members preferably have thin or tapered outer peripheral edges so as to cause minimum resistance to raising or lowering of the device in the bore hole and may be located at the upper and lower ends of the device.

In the above description, the device largely is described with reference to pumping of a liquid from a bore hole. However, the device is suited to a wide variety of other applications where pulsed pumping is appropriate or acceptable. One important use for the device is as a pump for use in solar heating or in desalination by means of solar or other heating. In such application, the device can be used independently of an external pressure source for the supply of fluid to the pressurizing compartment. In such case, the pressurizing compartment is closed and contains a fluid which, at the operating temperature range for the device, can be vaporized and condensed in successive cycles to vaporize and condense the fluid, by alternately applying and removing heat energy, so as to alternately pressurize and depressurize the pressurizing compartment.

In such closed cycle form of the device, the housing

most conveniently is of metal to provide good heat transfer between the exterior of the device and the pressurizing compartment. In one arrangement the application of heat to the fluid in the pressurizing compartment is effected by heat transfer through the housing; with the extraction of heat from that fluid being effected by heat transfer through the diaphragm to the liquid passing through the discharge compartment. However, the alternative arrangement is possible, with heat being supplied by the liquid passing through or adjacent the discharge compartment and extracted through the housing. In either case, the housing can be located within a container having an inlet port and an outlet port; a liquid to supply or extract heat being charged to the inlet port, for flow through the container around the housing of the device to exit from the outlet port.

In such arrangement, water pumped by the device can be passed to a solar heating panel, with output water heated in such panel before passing to the inlet port of the container of the device surrounding the housing. In such case, vaporizable liquid in the pressurizing compartment is vaporized by solar heated water flowing from the panel to increase the pressure in that compartment and pump cold water received from a source into the discharge compartment. Heat energy in the vaporized liquid is extracted through or adjacent the membrane the compartments into liquid remaining in the discharge compartment, resulting in condensation of the vaporizable liquid. Further water from the cold water source then is able to be drawn or forced into the discharge compartment and the cycle repeated.

A variety of arrangements for extracting heat from the system are possible. For example, the cold water passing to the discharge compartment initially may be relatively hot water which has been used to heat the vaporizable liquid and which, after issuing from the device, has its heat content lowered by passage through a heat exchanger. Heat energy taken up by the heat exchanger can be absorbed by mains water passing through the heat exchanger for heating prior to domestic use. Alternatively, the relatively hot water which has been used to heat the vaporizable liquid may pass to a hot water storage tank for use,

as required; with make-up water from a mains supply passing directly to the discharge compartment.

The device can readily be adapted for desalination of brackish bore water or sea water. In such case, the device can be mounted to receive heat from a parabolic reflector panel to vaporize a liquid in a closed pressurizing chamber, as described above. Water received in the discharge compartment of a device in such arrangement is maintained under pressure and, by incorporating in a support member a reverse osmosis membrane as described above, water of reduced salt content can be caused to pass through the membrane for discharge under such pressure. In such case, it is necessary to include a further outlet for the discharge compartment for periodic discharge of a residue of the feed water and resultant increased salt-content of this. The inlet to and the further outlet from the discharge compartment can each include a respective valve and, if necessary, these can be time controlled for intake of fresh feed water and discharge of residue water in each cycle.

One convenient form of support member is a perforate tube extending intermediate the inlet and outlet such that the latter always are in communication. The perforate tube should have sufficient stiffness to withstand substantial constriction under the forces resulting from pressurization of the pressurizing compartment. However, such tube needs to be bendable if, as described above, the device housing is to be bendable. The wall of the tube preferably is perforate over its entire length such that all of the portion of the liquid being pumped that is received in the discharge compartment and is exterior to the tube can be discharged during pressurization of the pressurizing compartment.

As will be appreciated, the provision of a support member within the discharge compartment or a configured inner surface for the diaphragm reduces the quantity of liquid that can be discharged from the device during each cycle. However, this disadvantage can be very slight and is acceptable, particularly as the device is substantially inoperable without use of such means for limiting diaphragm constriction within the discharge compartment. Also, it is to be

appreciated that when the discharge compartment is filled, the diaphragm or membrane can flex or bulge outwardly such that the volume of the discharge compartment then is significantly increased. This latter factor, in combination with relatively small volume possible for the means limiting constriction, . enables the quantity of liquid to be discharged from the device during each cycle to be high in relation to the total quantity of the liquid able to be held by the discharge compartment prior to discharge.

One suitable form of support member of tubular form has circumferentially extending arcuate slots through its wall. Such slots preferably extend around substantially the full circumference of the support member and are closely spaced along its length; the overall effect being that of a cylindrical mesh structure. Other arrangements are possible, such as a cylinder or tube having an array of holes or apertures through its wall. However, it is desirable in each case, that the slots, holes or apertures are not bounded by sharp edges at the exterior surface of the support member such as would result in damage to the diaphragm during repeated use of the device. In the latter regard, it will be appreciated that during pressurization of the pressurizing compartment to discharge liquid from the device, the pressurized fluid will deform the diaphragm into the slots or holes, resulting in it being damaged or worn by sharp edges.

It is to be appreciated that the support member need not extend fully between the inlet and outlet of the device. That is, undesirable constriction of the diaphragm adjacent the outlet can be prevented by a support member, such as of the above described forms, which is mounted adjacent the outlet and extends a sufficient distance toward the inlet.

In order that the invention may more readily be understood, description now is directed to the accompanying drawings, in which:

Figure 1 schematically illustrates a bore water sampling device;

Figure 2 shows a modified form of the device;

Figure 3 shows a further modified device for

collecting surface water;

Figures 4A and 4B show two further modified devices, respectively for sampling the top layer of ground water and surface water;

Figures 5A and 5B show respective tandem arrangements for sampling two adjacent levels in the bore hole;

Figure 6 shows an arrangement for a device similar to that of Figure 2 as used for inter-aquifer tests;

Figure 7 shows an arrangement for a dual bore hole sampling or dewatering;

Figure 8 shows a modified form of the device of Figure 1 including a support member applicable to the device(s) of each of Figures 2 to 7;

Figure 9 shows on an enlarged scale the support member of the device of Figure 8;

Figures 10A to 10E show modified forms of the device of Figure 1;

Figures 11A and 11B show further modifications for surface sampling;

Figure 12 shows a device according to the invention;

Figure 13 shows a further device;

Figure 14 shows the device of Figure 13 in use;

Figure 15 shows schematically the manner of use of a device as in Figure 12 or 13;

Figures 16A to 16D show respective views of a further modified device, with Figure 16E illustrating the cycle of operation;

Figure 17 shows a still further form of device, operating in the manner of the device of Figures 16A to 16D, for filtering desalination or reverse osmosis;

Figures 18 and 19 respectively show a device operating in the manner of Figures 16A to 16D with a solar heating panel and a solar reflector;

Figure 20 shows a preferred form of one-way valve for use in the devices shown; and

Figure 21 shows a device operating in the manner of Figures 16A to 16D to drive a motor.

With reference to Figure 1, the device 10 has a rigid plastics housing 12 of cylindrical form and having end

walls 14. At the top and bottom one of walls 14, there is an upper one-way outlet valve 16 and a lower one-way inlet valve 18, respectively, between which extends a tubular, flexible diaphragm or membrane 20. The latter divides the interior chamber of housing 12 into a discharge compartment 22 within a pressurizing compartment 24. Diaphragm 20 is shown in solid outline in its normal or relaxed condition and, in broken outline, in a bulged or expanded condition when liquid to be pumped is drawn or forced into compartment 22 through valve 18.

Device 10 is shown in a bore hole 26 for obtaining liquid to be sampled from the level at which slotted or screened bore section 28 is defined (and shown by broken outline). At the upper and lower end of device 10 there is a resilient, disc-shaped packer member 29 for sealing off the section of the bore portion from which the sample is to be taken from water entering the bore from higher or lower levels.

In use, water is either drawn into compartment 22 by

evacuating chamber 24 or forced into chamber 22 under the prevailing pressure in bore hole 26. The water enters through valve 18 via filter 30, with diaphragm 20 being flexed to its bulged condition. Thereafter, compartment 24 is pressurized by compressed air supplied thereto by pipe 32 to squeeze diaphragm 20 and discharge the liquid in compartment 22 through valve 16. The discharge liquid passes via outlet pipe 34 as is collected at ground level as the, or part of, a required sample for testing.

Pressurization of compartment 24 may be by a compressed air source at ground level. Release of pressure in compartment 24 when liquid is received into compartment 22 may be by venting compartment 24 to atmosphere, via a suitable valving device for pipe 32; by switching pipe 32 to a vacuum or low pressure source; or by a further pipe connecting compartment 24 to an evacuating source at ground level.

In device 10 as so far described, operation as indicated would result in diaphragm 20 constricting across valve 16 to block discharge, or constricting completely on completion of discharge so as to form a vacuum therein along at least a part of its length. This can not be readily or reliably overcome, notwithstanding evacuation of compartment 24, even in the case of a vacuum in compartment 22 if aided by substantial water pressure in bore 26. To overcome this difficulty, a support member 36 such as shown in Figure 9 is located within compartment 22 and restrains diaphragm 20 against full constriction so that communication is retained between outlet and inlet valves 16,18.

Member 36 is in the form of a perforate tube supported co-axially within diaphragm 20 between valves 16,18. Its cross-section preferably is small in relation to that of dipahragm 20 in the relaxed condition of the latter to maximise the quantity of water able to be discharged in each cycle of operation of the device.

The arrangement of Figure 2 is similar to that of Figure 1 except that water is received from a lower level to that at which housing 12 is located. This is permitted by extension pipe 40. As shown the packers 29 are provided at the lower end of pipe 40; while filter 30 is between the packers 29.

The device of Figure 3 is for taking a sample from surface water. Overall, the arrangement is similar to that of Figure 2 except that pipe 40 terminates in laterally extending intake arms 42 having inlet apertures 44 and in which filters are provided. The device is positioned above the surface water, with arms dipping below the surface to permit intake of a sample through apertures 44 without disturbing any stratification of the water.

Figures 4A and 4B show variants on Figures 1 and 3. In each case, the device is in a shell 46 surrounding the housing and permitting the water to be sampled to flow down between the shell and housing to inlet valve 18.

Figures 5A and 5B show respective tandem arrangements based on devices as in Figure 1. In the case of Figure 5A, sample liquid is taken from each of two levels, with that from the lower level being discharged from the lower device through the upper device, and pressurization of compartment 24 of each device being by a respective pipe 32. In the case of Figure 5B, liquid from each device is discharged through a respective pipe 34, while pressurization of their compartments 24 is via a single pipe 32 and a connector 33. However, it is to be understood that each device may have a respective pipe 32 and a respective pipe 34.

With reference to Figure 6, there is shown an arrangement for obtaining sample water from a lower aquifer A through an aquitard or aquiclude B. In this, the packer seals against the wall of the bore where it extends through the aquitard or aquiclude, and prevents contamination of the water from the lower aquifer by water entering the bore hole, such as from an upper aquifer C.

In the arrangement of Figure 7, a device is shown in each of two bore holes on respective sites of a dump site D or excavation. The devices can be operated so as to lower the level of ground water between the bores by drawing water from between them, or to obtain samples for analysis to determine the extent or rate of contamination of the ground water from the dump site or excavation.

In the modified form of the device of Figure 1 shown in Figure 8, a support member 50 extends through compartment

24 between valves 16,18. Member 50 is of tubular form and, as shown in Figure 9, has a plurality of acute, circumferential slots 51 formed over its surface. During operation of the device, member 50 prevents membrane 20 from collapsing adjacent valve 16 so as to prevent discharge of water through the latter on pressurization of chamber 24. Also as shown in the portion of member 50 depicted as broken-away, a body of porous material 52 can be provided within member 50. Material 52 may, for example, be a filter of diatomaceous earth, alumina or charcoal serving to filter fine solids from the water prior to discharge through outlet valve 16. Such material, or other known absorbents, can also be provided to remove some dissolve contaminants present in the water. Alternatively, material 52 can comprise beads of ion-exchange resin suitable for extracting salts from the water prior to discharge through outlet 16.

Where material 52 is of diatomaceous earth, alumina or other suitable material able to be formed into a sufficiently strong, porous mass, a rod of the material 52 can be used without a casing provided by member 50. That is, such rod 52 can be used alone to remove suspended or dissolved contaminants from the water, and also to serve the same function as member 50 in acting to limit constriction of diaphragm 20. The porous nature of the rod retains communication between valves 16,18 such that repeated pulsed operation of device 10 can be performed efficiently.

It is to be understood that a support member 50 and/or such rod of porous material 52 can similarly be provided in the devices of Figures 2 to 7. Additionally, it is to be understood that member 50, or such rod 52 (whether used with member 50 or alone), need not extend all the way from valve 16 to valve 18 and need only extend from valve 16 a distance sufficient to prevent membrane 20 from collapsing so as to prevent diaphragm 20 from collapsing adjacent valve 16 and to creation of a vacuum in diaphragm 20 acting to stop the repeated intake of water into compartment 22 via valve 18. Also, where member 50 does not extend to valve 18, it need not be of perforate form as its bore enables the water being discharged to pass to valve 16.

Figure 9 shows on an enlarged scale the form of support

member 50. Such member can be formed of a suitable plastics material or of a metal. Also, it is to be appreciated that a similar form of member can be formed from imperforate plastics or metal tubing which has been longitudinally slit and expanded to provide a perforate mesh structure.

In Figures 10A and 10B, a further modified form of the device of Figure 1 is shown. In this, housing 12 has concentric inner and outer walls 54,56 with wall 54 defining a passage 58. This arrangement enables the device to operate at an upper level in a bore in which second device is operating at a lower level; with the air and water pipes for the second device extending through passage 58 for concurrent operation of both devices.

The device of Figures 10A and 10B normally does not warrant inclusion of a support member of the form shown in Figure 9. However, a porous liner 57 can be provided on the inner surface of wall 54 to retain communication between valves 16,18 with diaphragm 20 constricted; liner 57 being of any suitable material, such as those described in relation to rod 52 (Figure 8). Where such porous or perforate liner 57 is not provided, the outer surface of wall 54 or the inner surface of diaphragm 20 must be configured, such as in the manner shown in Figure 10C or 10D, to retain communication between valves 16,18.

Figures 10C and 10D show alternative surfaces for use in the device of Figures 10A and 10B. In the arrangement of Figure 10C, there is shown a surface 60 having a parallel array of ribs 61, between which are defined channels 62. Surface 60 may be the inner surface of diaphragm 20 or the outer surface of wall 54; although it will be appreciated that while shown flat, surface 60 will be convex or concave, respectively, in a direction transversely of device 10 of Figure 10A. The ribs 61 may extend axially, helically or, if discontinuous, circumferentially of the device such that, with diaphragm 20 constricted against wall 54, creation of a vacuum cutting communication between valves 16,18 is prevented due to flow in channels 62.

In the arrangement of Figure 10D, surface 60 has formed thereon an array of projections 63, which serve a similar function to rib 61. Surface 60 again would be convex or concave, although

shown flat; and with diaphragm constricted against wall 54, creation of such vacuum again is prevented by the spacing between projections 63.

Figures 11A and 11B show alternative forms of devices which are for sampling surface water. In contrast to those described above, each is suitable for use in a horizontal disposition, rather than the vertical disposition normally appropriate for the devices of Figures 1 to 8.

In the Figure 11A and 11B devices, the overall form is as for Figure 1. However, the device of Figure 11A has an elongate water inlet pipe 64 parallel to and above housing 12; with a filter preferably being provided in pipe 64. The device of Figure 11B is similar, but has its pipe 64 below housing 12.

In each of the arrangements of Figures 1 to 8, it is highly preferred that pipe 32 communicate with the upper end of housing 12 where the device is to be used for pumping bore water. This can be varied, although such communication normally will be necessary where the device is to be used in a bore hole of small diameter. However, particularly in the arrangement of Figures 11A or 11B, the pipe 32 may communicate at either end of housing 12, or intermediate its ends. Similar considerations apply to outlet pipe 34, as outlet valve 16 can be provided in the lower end of the latter rather than within housing 12. Also, as will be appreciated, there is substantial freedom in locating the inlet and outlet and, hence, valves 16,18, where the device is to be used in other applications.

The respective devices 10 of Figures 12 and 13 each are of a similar form overall to the device 10 of Figure 1. For brevity, differences only will be described, and for the remainder attention is directed to the description of Figure 1.

The device 10 of Figure 12 differs in that housing 12 has a flexible peripheral wall defining the chamber divided by flexible membrane 20 into compartments 22, 24. However, for convenience, it is shown as incorporating features of different embodiments in its upper and lower portions shown in section and solid outline, respectively.

Due to the flexible nature of the housing 12, the device can be inserted endwise into a non-linear bore hole,

conduit, duct or pipe 26. In such insertion, such as shown in Figure 15, device 10 is able to bend to follow a curved portion of the bore hole or the like. However, device 10 is constrained against inflation in use by reinforcement.

As shown in the upper portion of Figure 12, the reinforcement can be in the form of a helical coil 21 of wire or relatively non-extendable fibre or thread such as of nylon. However, as shown in the lower portion of that figure, the reinforcement can be a plurality of longitudinally spaced penannular members 23, of metal or stiff plastics material, each located in a respective one of circumferential grooves 25.

The device of Figure 13 is as for Figure 12 except that reinforcement is not provided. Thus, in use, the device is able to inflate (at least to the extent permitted by the bore hole 26 or the like).

As shown in Figure 15, either device 10 of Figures 12 and 13 can be inserted down the bore hole 26 or the like. If a curved portion 27 of hole 26 is encountered, the device is able to bend, due to the flexibility of housing 12, to follow the curvature of that portion. As with use in a linear portion of the hole, resilient packer members 29 continue to provide a seal at the respective ends of device 10, even in portion 27. However, it is to be appreciated that it may be necessary to increase the members 29 in diameter and/or resilience relative to the requirements for a device 10 for use in a linear hole to ensure sealing across the greater effective section of the hole that may be experienced in curved portion 27.

Use of each device 10 of Figures 12 and 13 is essentially as described in relation to Figure 1. However, as in the latter case, housing 12 of Figure 12 does not vary in cross-section in use (i.e. reinforcement 21 or 23 substantially prevents inflation). Also, the device of Figure 13 is able to inflate as shown in Figure 14.

If the pressure of liquid entering chamber 22 of the device of Figure 13 is sufficient, membrane 20 initially will bulge to engage the peripheral wall of housing 12. Thereafter, that wall of housing 12 also will bulge outwardly. The consequence of this, of course, has to be allowed for in

selecting the materials of construction for membrane 20 and housing 12, both to ensure their non-failure and also their ability to resume their former configuration. However, it is to be appreciated that such bulging is of practical advantage in that it increases the volume of liquid passing through chamber 22 in each cycle, while resilient recovery of housing 12 facilitates discharge of pressurized gas from chamber 24 at the end of each cycle.

It is to be appreciated that a number of variations on the foregoing are possible. In a first variant, reinforcement 23 or 25, either of which normally is provided over substantially the full axial extent of housing 12, can be embedded in the peripheral wall of housing 12. In a second variant, penannular members 25 can be substituted by continous rings or bands, and in a third variant these also can be embedded in, rather than around the outer surface of, housing 12. Also, in a still further variant the device of Figure 13 can have reinforcement 23 or 25 as in Figure 1, with this being a helical coil 23 having a degree of resilience or relatively flexible penannular members 25 (or rings); in each case the flexibility of the reinforcement being such that inflation of housing 12 still is possible within a required limit.

In the device of Figure 13, a support member is not provided; although such member could be provided in the manner of member 36 of Figure 1 provided it is of a material enabling it to bend with housing 12, as shown in Figure 15. Rather, the inner surface is configured, such as shown in Figure 10C or 10D, to prevent formation of a vacuum within diaphragm 20 when constricted to discharge liquid from chamber 22. However, for simplicity of illustration, such configuring is not shown in Figure 13.

In the device of Figure 12, a perforate support member 36 of a bendable tubular plastics is provided. As shown in Fig. 15 by broken outline, this member is able to bend with bending of housing 12, but has sufficient stiffness to withstand forces applied to it during constriction of diaphragm 22 with pressure increase in compartment 24.

With reference to Figures 16A to 16D, the device 110 is similar to that of Figure 1 and parts corresponding to those

of Figure 1 are identified by the same reference numeral, plus 100. Device 110 differs from Figure 1 essentially in that compartment 124 is entirely closed and contains therein a liquid 70 vaporizable under the intended operating conditions; while housing 112 is located within a container 68 for receiving heated liquid 69. In this instance, member 136 is as described in relation to Figures 1 and 9; with 70' being vapour of liquid 70.

In operation of the device 136, heat energy is applied to metal housing 112 and vaporizes liquid 70 to the gaseous state, generating substantial pressure in compartment 124 and constricting diaphragm 120 to the limit permitted by member 136. During such constriction, cold water previously drawn into compartment 122 via valve 118 is forced to discharge via valve 116; complete discharge being approached just prior to the condition shown in Figure 16A.

The inflow of cold water to be pumped is shown as just commenced in Figure 16A, after discharge of a previous quantity of that water. With continuation of that flow, despite continued application of heat energy, the vapour 70' in compartment 124 is cooled by heat extracted by the incoming cold water, through diaphragm 120 and heavy base wall 68'. In Figure 16B, compartment 122 is shown as substantially filled.

With continuation of input of heat energy to housing 112, re-vaporization of liquid 70 occurs, to return to the condition just preceding that of Figure 16A. During the resultant re-pressurization, the water taken into chamber 122 via valve 118 is discharged through valve 116 until constriction of diaphragm 120 is arrested by member 136. Figure 16E illustrates the pressure verses volume cycle in chamber 124, with points A to D corresponding to Figures 16A to 16D, respectively. As shown, conditions of substantially isothermal compression, adiabatic compression, isothermal expansion and adiabatic expansion occurs between the conditions of Figures 16A to 16B, 16B to 16C, 16C to 16D and 16D to 16A, respectively.

During the foregoing operation, a continuous flow of heat energy is applied to housing 112, such as by hot liquid 69 flowing in container 68 around housing 112 (although inlet and outlet ports for container 68 are not shown). However, it is to be appreciated that such input of heat energy can be discontinued

during the period in which condensation of vapour 70' is required. Also, such condensation can be made more rapid by extracting heat energy from housing 112, such as by switching to a flow of cold liquid through container 68. Additionally, it is to be appreciated that the cycle can be inverted for pumping hot water through compartment 122, such as hot thermal spring water, with heat extracted from this through diaphragm 120 resulting in the vaporization of liquid 70, and condensation of vapour 70' being achieved by cold water flowing around housing 112 in container 68.

With reference to Figure 17, the device illustrated operates in the manner of that of Figures 16A to 16D, and similar parts have the same reference numerals. However, in this instance, end walls 114 secure a removable water treatment cartridge 136 corresponding to the support member 36 of earlier embodiments, while the inlet and outlet for the device are at the one end of the device. Also, while there is an inlet valve 118, there is no outlet valve 116; while there is a second outlet 71 which is optional, depending on the nature of cartridge 136.

Cartridge 136 is retained in each end wall 114 by respective O-ring seal 72. As show, it is of cylindrical form, but has a central passage 73 which is closed at one end and at its other end defines an outlet 74 for the device.

In one form, cartridge 136 can be formed of a relatively densely packed, but porous filter material. Suitable materials include activated carbon for removal of flavour contaminants or colouring contaminants; manganese greensand or resin for removing dissolved iron and manganese; diatomite for removing suspended matter; zeolites for water softening; or a combination of such materials. Also, cartridge 136 may comprise or include fibrous filter material.

Alternatively, cartridge 136 may comprise or include ion-exchange resin, such as in bead form, for removal of salts, such as for desalination.

Operation with the device of Figure 17 is essentially as for the device of Figures 16A to 16D in that housing 112 is closed and a vaporizable liquid is held in compartment 124. However, in discharge of liquid from compartment 122 during a

pumping operation, the liquid is forced through cartridge 136 to passage 73 for flow from the device. The back-pressure to liquid flow through cartridge is one reason why a valve is not required at outlet 74.

In a further alternative, for which outlet 71 is provided, cartridge 136 comprises a reverse osmosis unit operable to provide removal of dissolved salts from water being pumped by the device. Cartridge 136 may comprise a suitable cylindrical reverse osmosis membrane supported on a rigid frame, or it may comprise a spiral wound membrane module of the Permutit-Body type. Under the pressure prevailing in compartment 122 with vaporization of liquid in and pressurization of compartment 124, the water in compartment 122 is forced through cartridge 136. Dissolved salts are extracted by cartridge 136 to enable fresh water to discharge through the outlet defined by passage 73; with water of increased salt content being retained in compartment 122. In each or periodic cycles, the salt enriched water in compartment 122 is extracted via outlet 71, the latter communicating with the interior of compartment 122 and having a suitable control valve.

The device of Figure 17 can be adapted for cleaning of cartridge 136 by back-washing. Alternatively, the cartridge can be removed for cleaning or replaced.

Figure 18 shows a simplified system for use of a device as shown in Figures 16A to 16D, or in Figure 17. In this, the device 110 is used as a pump in a solar heating or booster system; with the pump necessitating no external power source. In the system, device 110 is shown as having a container 68 enclosing its housing. Water heated in solar panel 80 passes via line 81 to container 68 and, in the latter, around the housing of the device to vaporize a liquid in the pressurizing compartment as described in relation to Figures 16A to 16D. The water then passes from container 68 via line 82, from which it is pumped back to solar panel 80 by device 110.

In heating the housing to vaporize liquid in compartment 124, the water received from line 81 is lowered in temperature. There thus is a temperature differential between that water, and the same water later received by within compartment 122. By appropriate choice of the vaporizable liquid, this cycle is

capable of operation in the manner of Figures 16A to 16D. Also, while the water in line 82 is of a lower temperature, it can still be at a temperature sufficient to provide at least low grade heating of water for domestic use. Thus, as shown, line 82 passes to a heat exchanger 83 where it gives up further heat; that heat being used to heat cold water for domestic use passing through exchanger 83 in line 84. The heat lost by the water in line 82 in exchanger 83 further increases the temperature differential to which the vaporizable liquid in compartment 124 is subjected; although the water passing through compartment 122 from line 82 extracts some make-up heat energy through diaphragm 120 in condensing the vaporizable liquid in compartment 124.

Figure 19 shows a device of Figure 17, having a reverse osmosis cartridge 136, in an alternative arrangement for supplying heat to housing 112 to vaporize the liquid in compartment 124. As shown, device 110 is mounted in a parabolic solar energy reflector 86; part of housing 112 being at the focus of reflector 86. While shown as extending transversely of the focal axis, it will be appreciated that device 110 could be mounted along that axis. Operation of the device 110 of Figure 19 is essentially as described in relation to Figure 17, apart from the source of the heat energy.

Figure 20 shows a preferred form of one-way valve 90 for use as the inlet and/or outlet valve of the device of the invention. Valve 90 is shown as movable vertically in controlling flow through opening 91. The valve has a body 92 having a conical portion 93 which of reducing taper in the direction of required one-way liquid flow. The taper of portion 93 is complementary to a valve seat 94 in opening 91, and, at its wider end has a resilient O-ring seal 95 located in groove 96 in body 92. A stem 97 extends beyond 92 and, inwardly of opening 91, carries an impeller 98. Pressure on domed head 99 of body 92 causes the valve to seal against flow in the upward direction, by seal 95 bearing against seat 94. However, with liquid pressure in the reverse direction, the valve is forced to unseat, with this being assisted by rotation imparted by impeller 98. The diameter of impeller 98 is greater than opening 91, so as to retain the valve in the

latter.

In the arrangement of Figures 16A to 16D, those of Figures 17 to 19, transfer of heat energy between compartments 122 and 124 can proceed to a substantial degree through diaphragm 120. However, the materials generally suitable for use in forming diaphragm 120 generally are not particularly good conductors of heat. Such heat transfer can be facilitated in the manner illustrated in Figures 16A to 16C, by providing a substantial body of metal adjacent at least one end of diaphragm 120. Additionally, or alternatively, the transfer of heat through diaphragm 120 can be enhanced by incorporating a heat conducting material in the material of which the diaphragm is made. Thus, without impairing the ability of the diaphragm to flex, it can incorporate particles or threads of metal, carbon or other such materials which facilitate heat transfer.

The device of the invention is capable of discharging liquid from the discharge compartment at substantial pressure levels. Thus, with a device as in Figure 1, pressures in excess of 10 bars can be generated. Such pressure level is obtainable with a housing of internal diameter of 40 mm and length of 600 mm, and spacer of 15 mm diameter, when the device is operated in the manner described in relation to Figures 16A to 16D, under isothermal conditions using feed water at 65°C for the pressurizing compartment and feed water at 15°C for the discharge compartment. A pressure substantially in excess of 10 bars is possible with a larger device and/or operation at higher temperatures.

The pressure able to be generated is such that the device is capable of use as a power source. This is illustrated in Figure 21, in which a pair of devices 110 as in Figures 16A to 16D, are shown in association with a hydraulic engine 201. The devices 110 are in a parallel arrangement, with the inlet valve 118 of each receiving water via line 202. However, container 68 in this instance defines a combustion chamber into which is directed a suitable fuel via burner nozzle 203. Combustion of the fuel, such as kerosene, oil, gas or coal dust, provides continuous heating of the housing 112 of each device and provides heat energy for vaporizing a suitable liquid in the respective pressurizing compartments.

Valves 118 are controlled by suitable means so as to open and close as required, such that devices 110 operate out of phase. The liquid is discharged alternately from each device into a single outlet line 204, via valves 116, with the pressure of the discharged liquid being used to drive engine 201. From the latter, the water returns in line 202; with heat energy being extracted from the liquid in line 202 either by cooling fins on that line or by heat exchanger 205.

With further reference to Figures 16A to 16D, and Figures 17 to 19 and 21, it will be appreciated that the choice of vaporizable liquid will depend on the temperature range at which the device is to be used. However examples of suitable liquids are the fluorocarbon gases such as available under the trade mark FREON, water, alcohol and ether.

Where the diaphragm is required to transfer heat energy between the pressurizing and discharge compartments, it can as indicated above incorporate particles or threads of material which facilitate heat transfer at a greater rate than the main or matrix material of the diaphragm. However, without loss of the necessary resilience of the diaphragm, other alternatives are possible. Thus, as shown in Figure 10E, a suitable diaphragm 236 can be provided with cut-out portions to define windows 206 in which are mounted thin metal sheets 207. Windows 206 can take a variety of forms, such as the longitudinal strip form illustrated. However, they can also be of shorter length and of other shapes such as circular. Also, where the sheets or elements 207 are of strip form they can extend other than axially.

The sheets 207 can be secured to the diaphragm body by any suitable means, such as by vulcanizing. Their presence greatly facilitates heat transfer between the pressurizing and discharge compartments due to their greater conductivity. They can, as a consequence, reduce substantially the level of heat energy to which the body of the diaphragm is exposed by rapid transfer of heat energy, and additionally shorten the duration of each cycle of operation of the device. Moreover, such windows with heat transfer sheets can comprise a form of configuration of the diaphragm surface which limits constriction of the diaphragm so as to retain communication between the inlet

and outlet of the discharge compartment.

Diaphragm 136 most conveniently has at each end a portion 208 in which such windows are not provided. This facilitates securement of the end portions 208 within the housing device and, as with other embodiments of the invention, securement of the diaphragm ends can be by any suitable means such as heat sealing, retaining clips or clamps, or securement between inter-fitting portions of the device housing.

The diaphragm separating the pressurizing and pumping compartments can be of a wide variety of resilient materials. However, where a vaporizable liquid is to be used in the pressurizing compartment, a particular constraint is compatibility with that liquid, as well as stability at the temperature range to be used for that liquid. Depending on the vaporizable liquid, the membrane can, for example, be of Teflon, Silicon rubber, synthetic rubbers such as butyl rubber and the rubber sold under the trade mark Viton, and natural rubbers. These materials can also be used where a vaporizable liquid is not provided; while, in each case, other natural or synthetic materials can be used to form the membrane.

Finally, it is to be understood that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts previously described without departing from the spirit or ambit of the invention.

CLAIMS

1. A liquid handling device having: a housing defining a chamber and having an inlet and an outlet; a non-return valve at at least one of the inlet and outlet; and a flexible tubular diaphragm within the housing and dividing the chamber into two compartments, one of the compartments (the discharge compartment) providing communication between the inlet and the outlet and the other of the compartments (the pressurizing compartment) extending around the discharge compartment with the arrangement being such that with a quantity of liquid received in the discharge compartment via the inlet, an increase of fluid pressure in the pressurizing compartment causes the diaphragm to be constricted to discharge the liquid in the discharge compartment through the outlet; the device further including means within the discharge compartment to limit constriction of the diaphragm to an extent that communication is maintained between the inlet and outlet during discharge.

2. A device according to claim 1, wherein said means for limiting constriction of the diaphragm comprises a support member extending within the discharge compartment.

3. A device according to claim 2, wherein said support member acts to provide a physical obstruction preventing substantially complete constriction of the diaphragm.

4. A device according to claim 3, wherein said support member is of elongate form and has a cross-section of cruciform or star-shaped form.

5. A device according to claim 3, wherein said support member is of tubular form.

6. A device according to claim 3, wherein said support member is in the form of an elongate porous rod.

7. A device according to any one of claims 2 to 6, wherein said support member includes porous filter material through liquid to be discharged from the outlet is able to pass to remove solids entrained in said liquid.

8. A device according to any one of claims 2 to 6, wherein said support member includes ion-exchange resin through which liquid to be discharged from the outlet is able to pass to enable extraction of salts dissolved in said liquid.

9. A device according to any one of claims 2 to 6, wherein

said support member includes a reverse osmosis element through which liquid to be discharged from the outlet is able to pass at a reduced salt concentration.

10. A device according to claim 1 wherein said means for limiting constriction of the diaphragm comprises a configured surface provided on the surface of said diaphragm facing inwardly of said discharge compartment.

11. A device according to claim 1, wherein said housing is of annular form, with said diaphragm being disposed substantially concentrically between inner and outer cylindrical walls, said means for limiting constriction of said diaphragm comprising a configured surface provided on the outer face of said inner wall.

12. A device according to claim 10 or claim 11, wherein said configured surface is characterised by ribs defining channels therebetween, said channels providing communication between said inlet and outlet when said diaphragm is constricted.

13. A device according to claim 10 or claim 11, wherein said configured surface is characterised by a plurality of projections around and between which the inlet and outlet are in communication when said diaphragm is constricted.

14. A device according to any one of claims 1 to 13, wherein said housing is of cylindrical form, with the diaphragm extending longitudinally within said housing.

15. A device according to any one of claims 1 to 13, wherein said pressurizing compartment is provided with at least one port enabling fluid pressurization of said pressurizing compartment from a location exteriorly of said housing to effect constriction of said diaphragm.

16. A device according to any one of claims 1 to 14, wherein said pressurizing compartment is closed and contains a vaporizable liquid such that application of sufficient heat energy to said vaporizable liquid generates vapour of the latter to pressurize said pressurizing compartment, and extraction of sufficient heat energy enables condensation of said vapour to depressurize said compartment.

17. A device according to claim 16 wherein said housing is of metal to facilitate said application and extraction of heat

WD.

energy.

18. A device according to claim 16 or claim 17, wherein said diaphragm is adapted to facilitate transfer of heat energy between said pressurizing and discharge compartments to enable said application or extraction of heat energy by the liquid to be received in and discharged from said discharge compartment.

19. A device according to any one of claims 16 to 18, wherein transfer of heat energy between said pressurizing and discharge compartments is facilitated by a portion of said housing.

20. A device according to any one of claims 16 to 19, including a container in which said housing is located, said container having an inlet port and an outlet port for enabling flow of heat transfer fluid over said housing, the inlet and outlet of said discharge compartment extending through said container.

21. A device according to any one of claims 1 to 20, including a solar water heating panel for solar heating of a liquid, the outlet of said discharge compartment being in communication with liquid flow defining means of said panel to permit liquid discharged from said discharge compartment to pass to said panel.

22. A device according to any one of claims 1 to 20, including a solar reflector panel in relation to which said housing is mounted to receive reflected heat energy from said panel.

23. A device according to any one of claims 1 to 20, including a hydraulic engine, the outlet of said discharge compartment being in communication with an inlet to said engine such that liquid discharged from said discharge compartment can be applied to and drive said engine.

24. A device according to claim 10, wherein said configured surface is provided by cut-out portions of the diaphragm over which sheet metal elements are secured, said elements facilitating transfer of heat energy between said pressurizing and discharge compartments.

25. A device according to any one of claims 16 to 23, wherein said diaphragm has cut-out portions over which sheet metal elements are secured, said elements facilitating -

transfer of heat energy between said pressurizing and discharge compartments.

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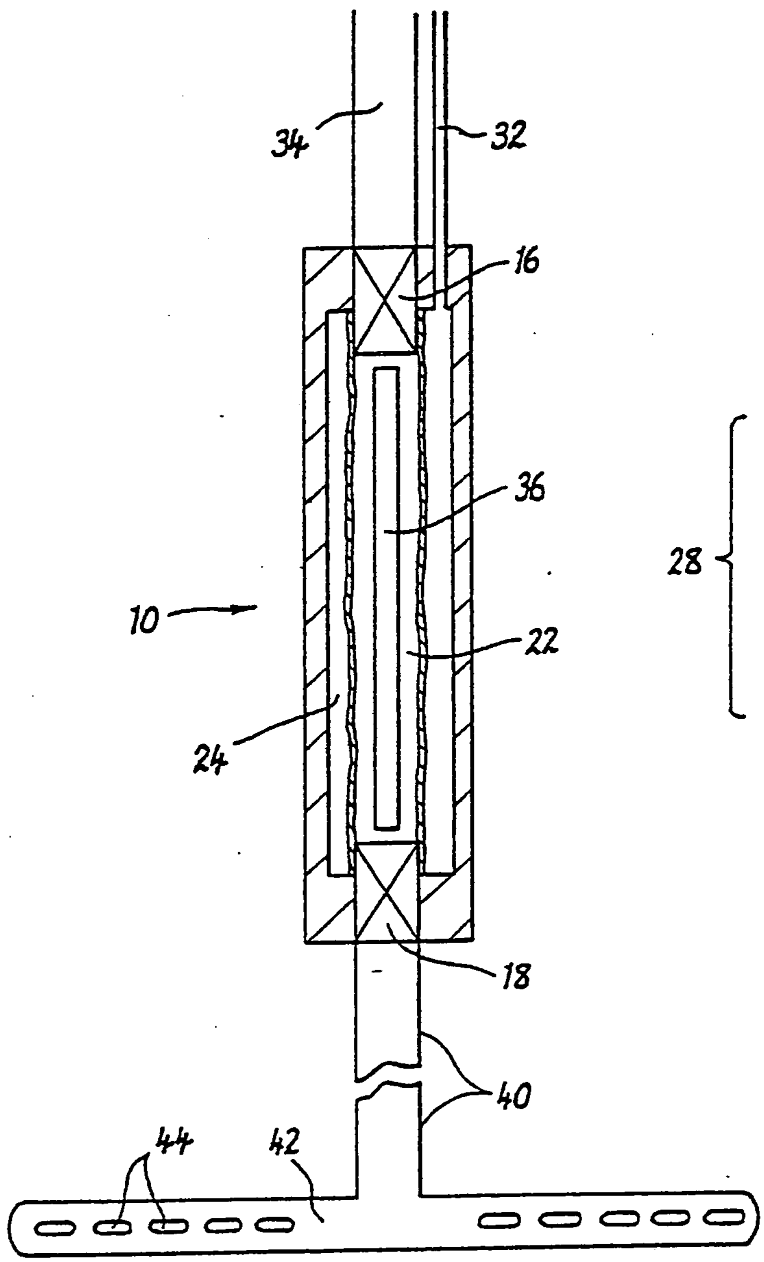

FIG. 3

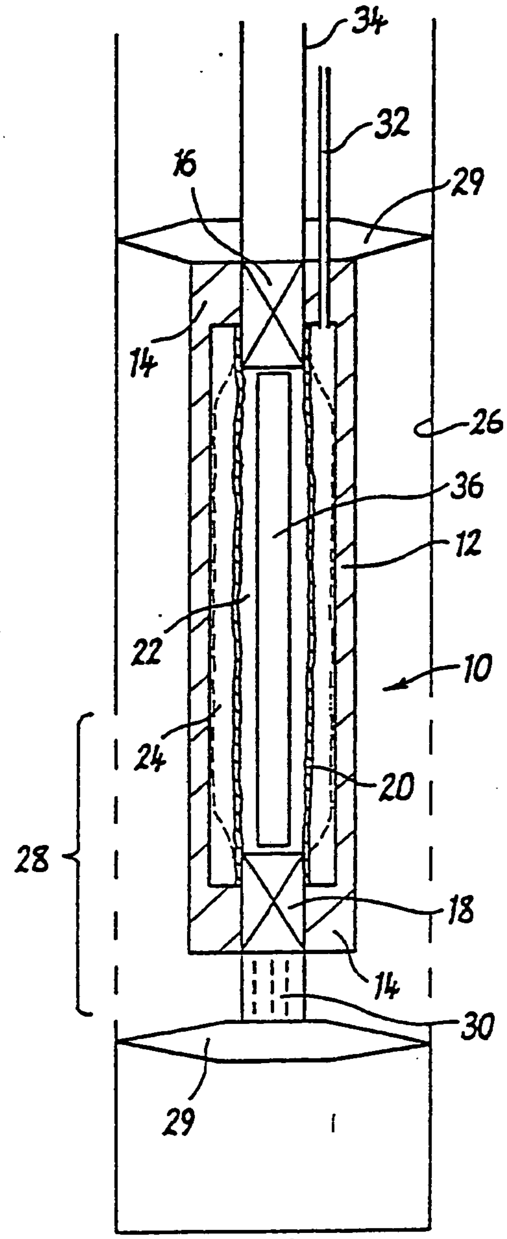

FIG. 1

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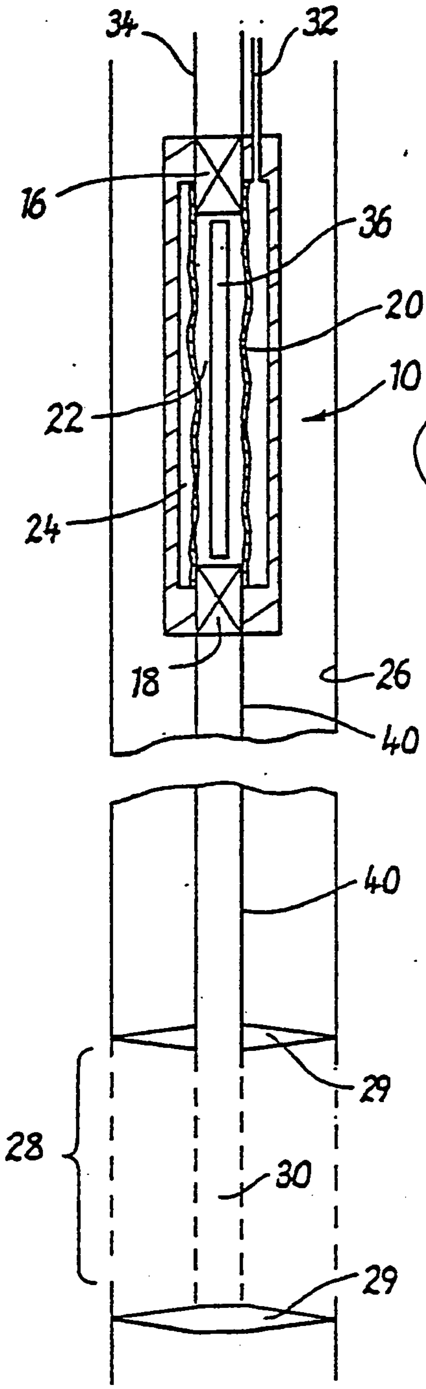

FIG. 2

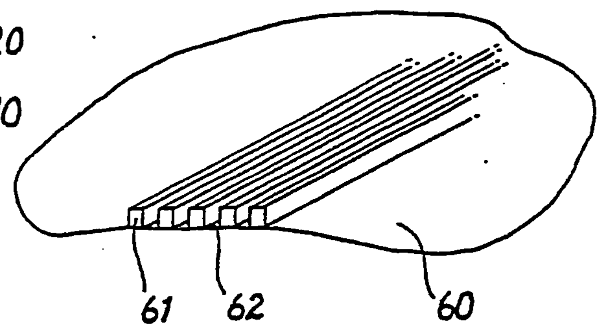

FIG. 10C

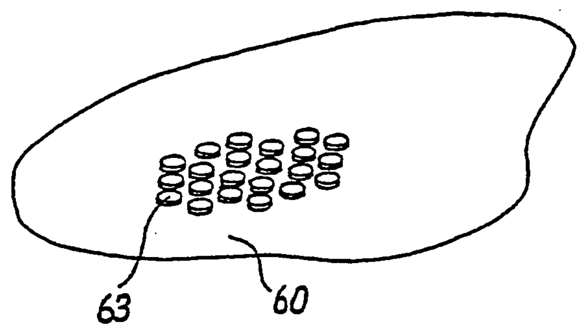

FIG. 10D

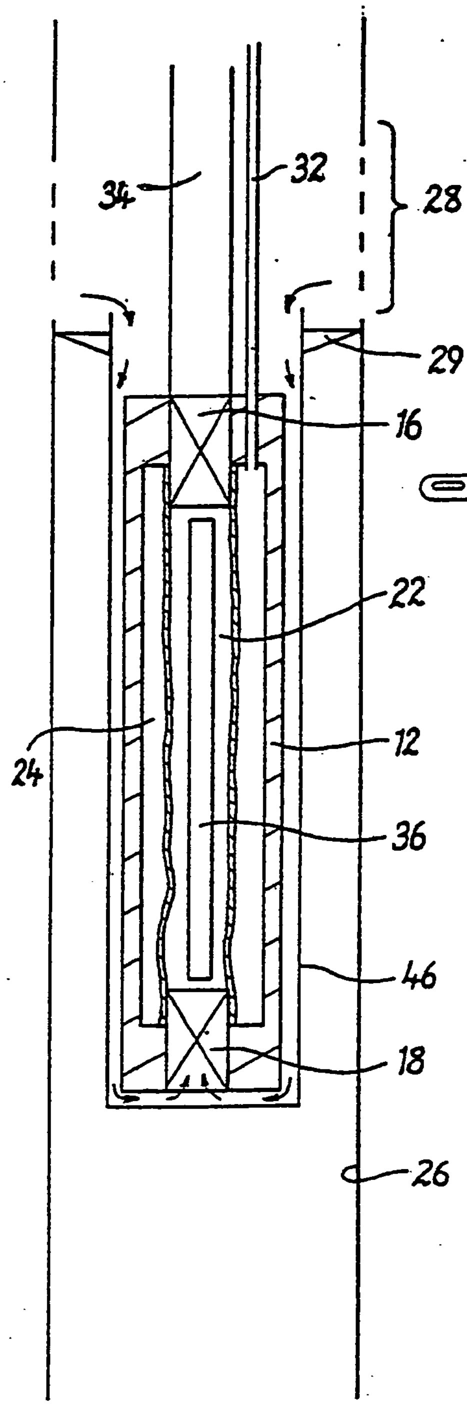
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FIG. 4A

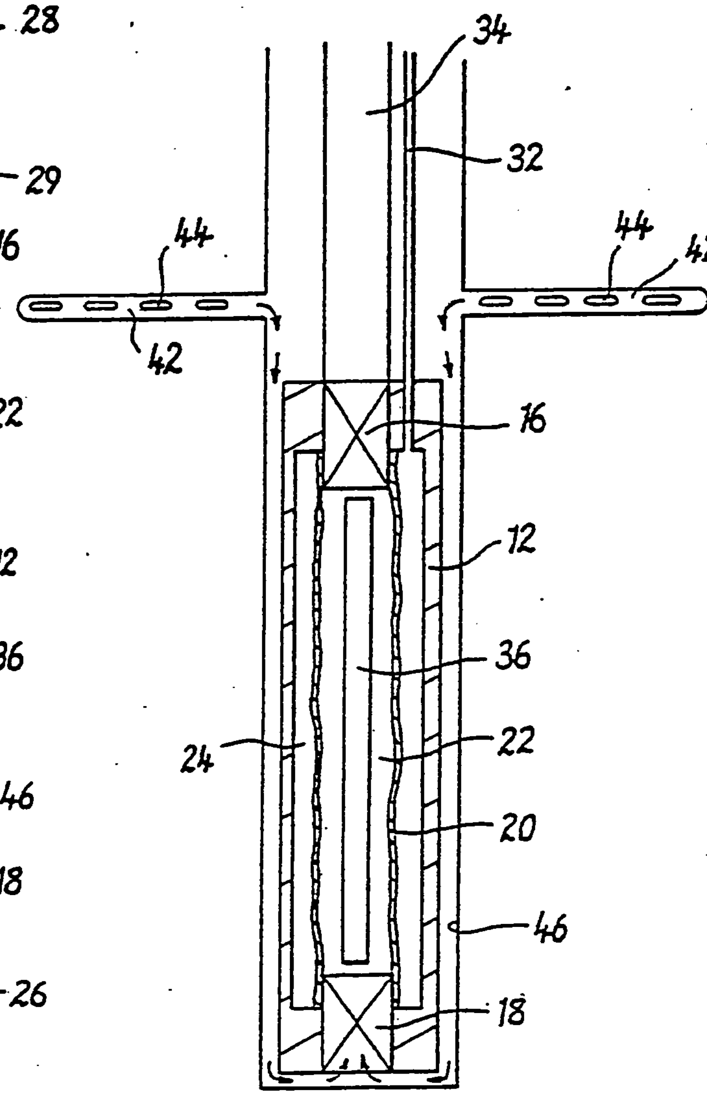
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FIG. 4B

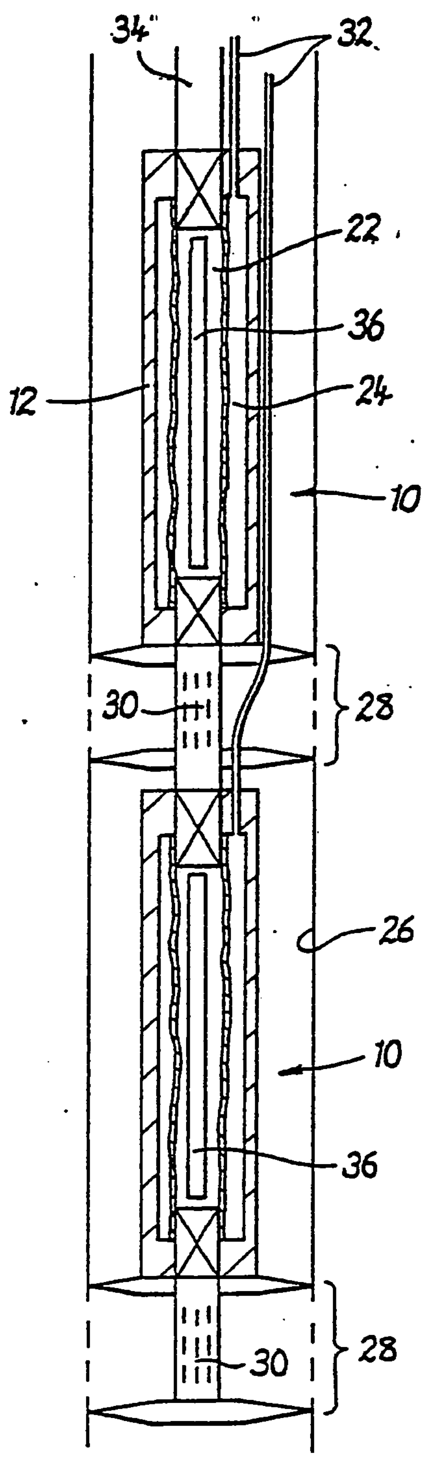
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FIG. 5A

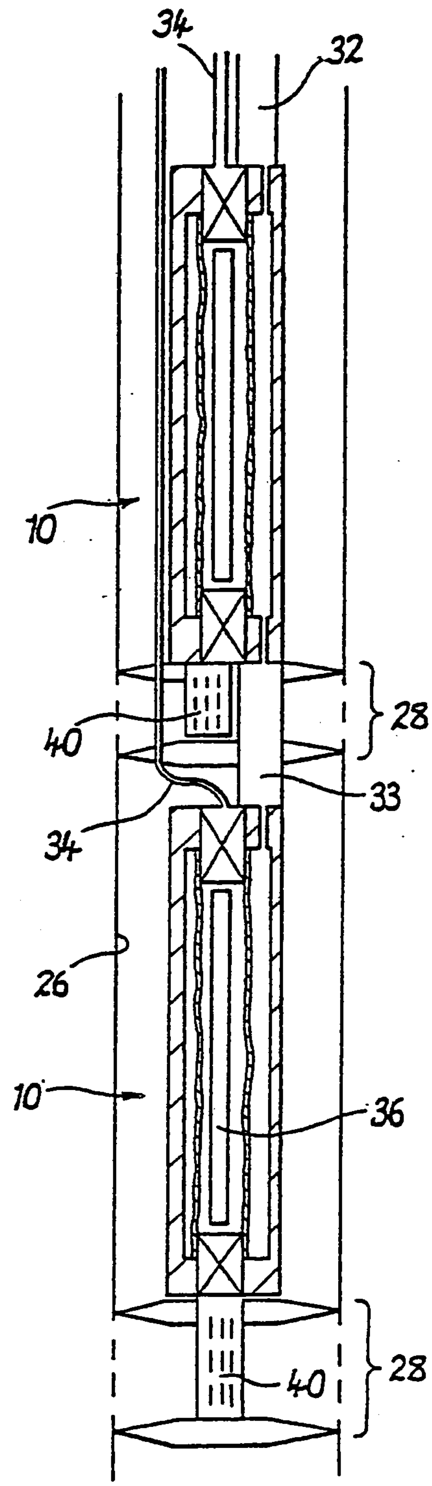
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FIG. 5B

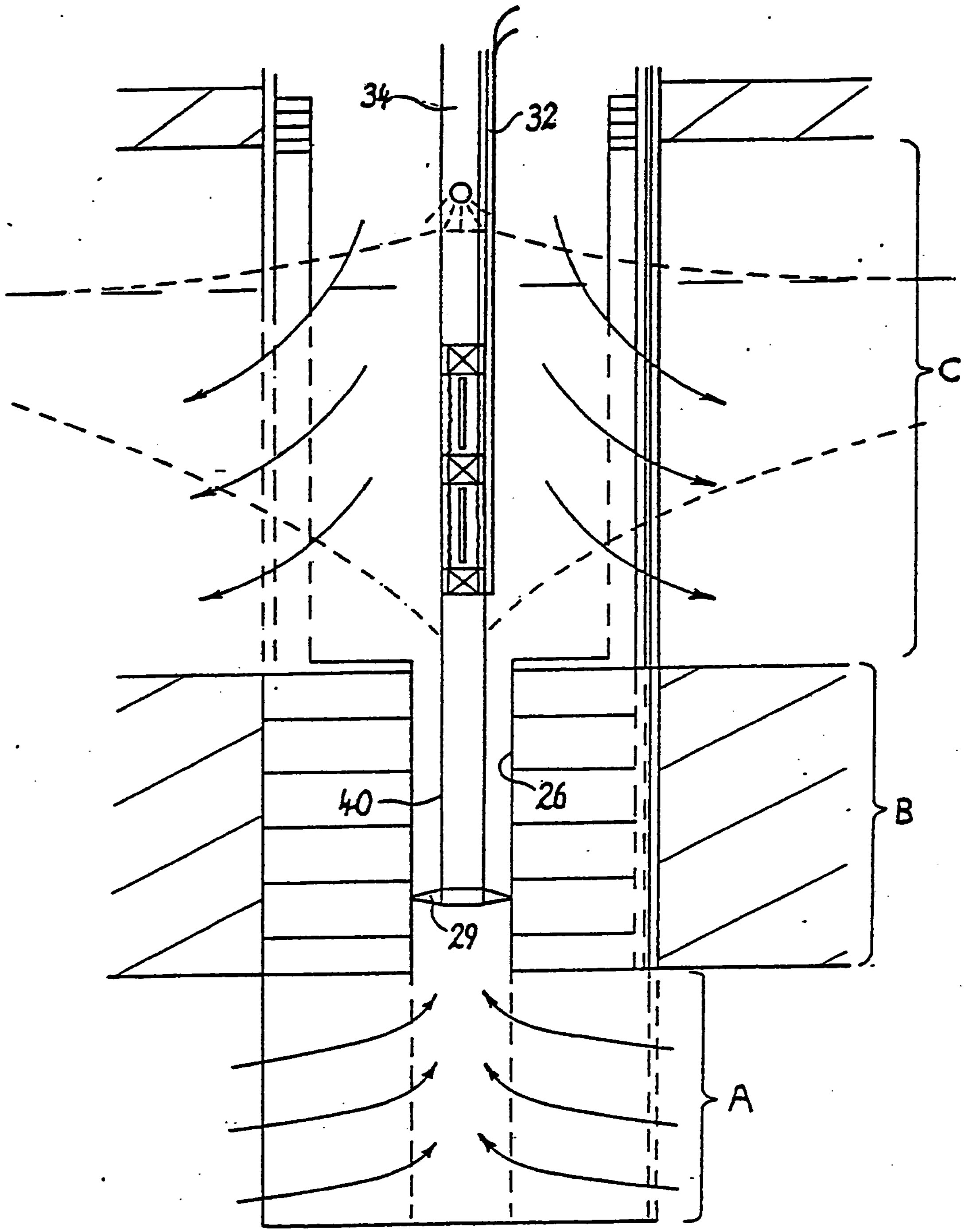

FIG. 6

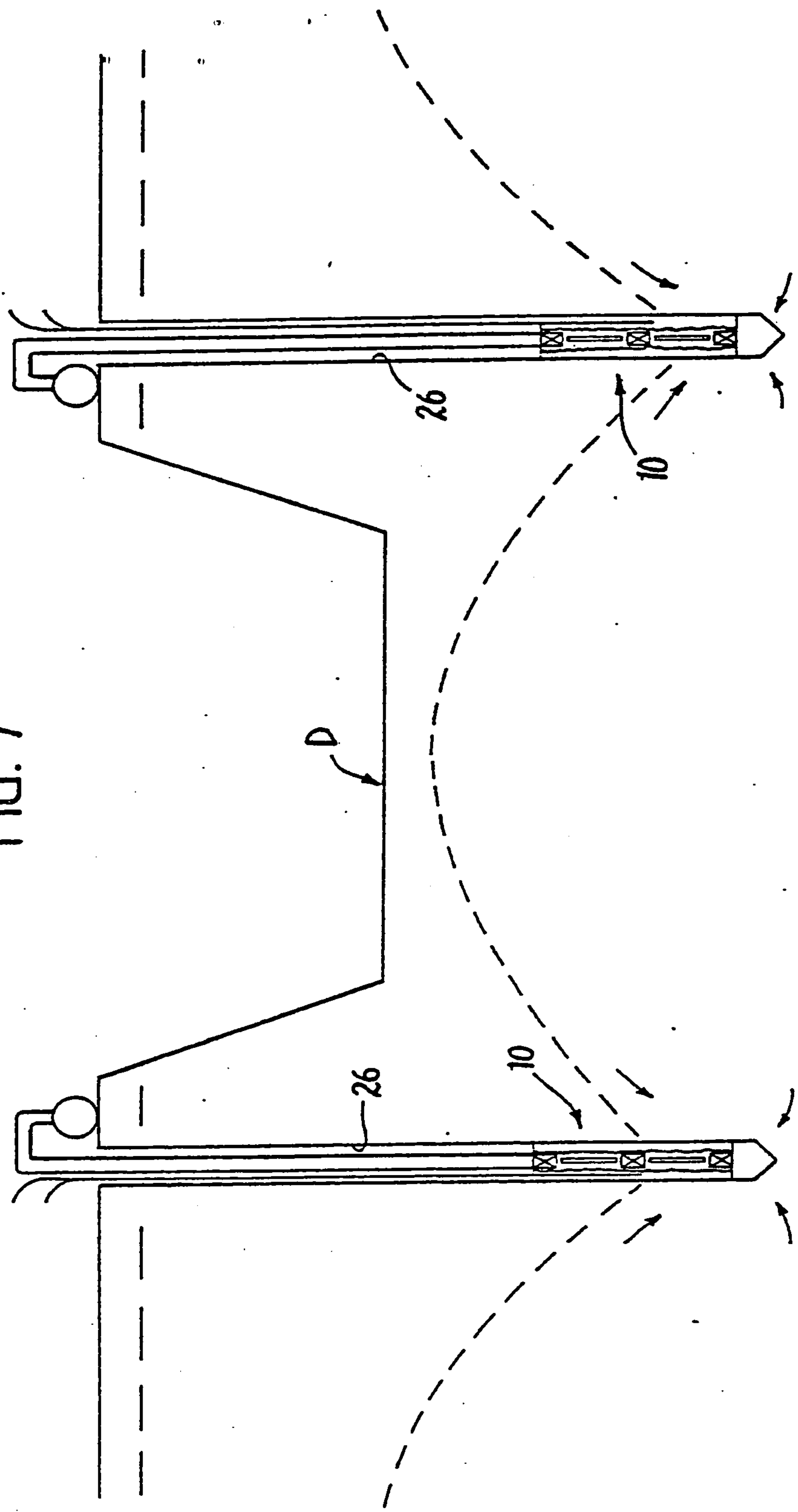

FIG. 7

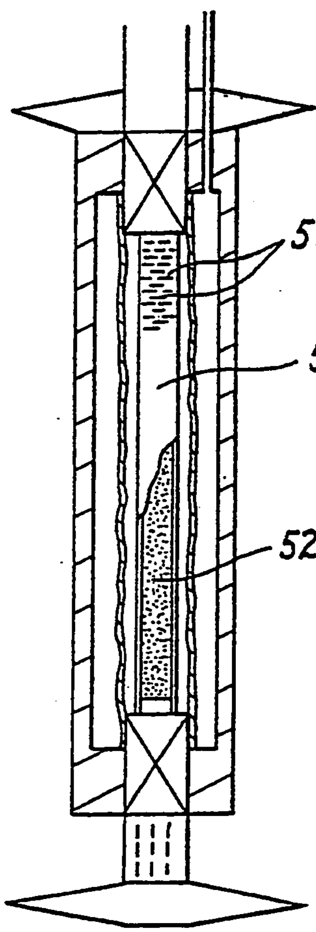

FIG. 8

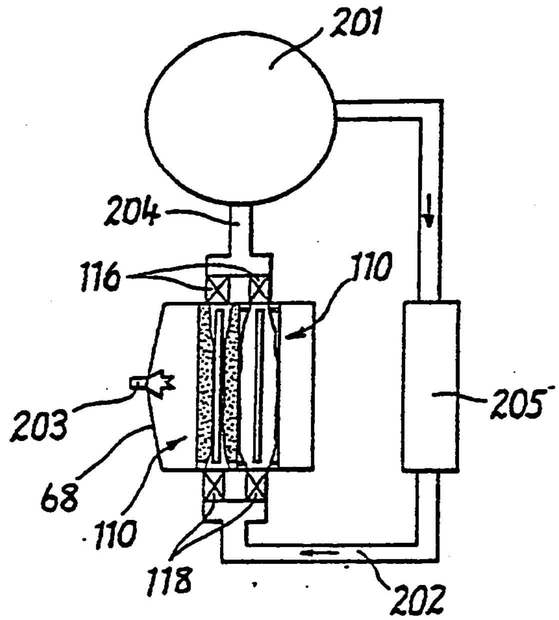

FIG. 21

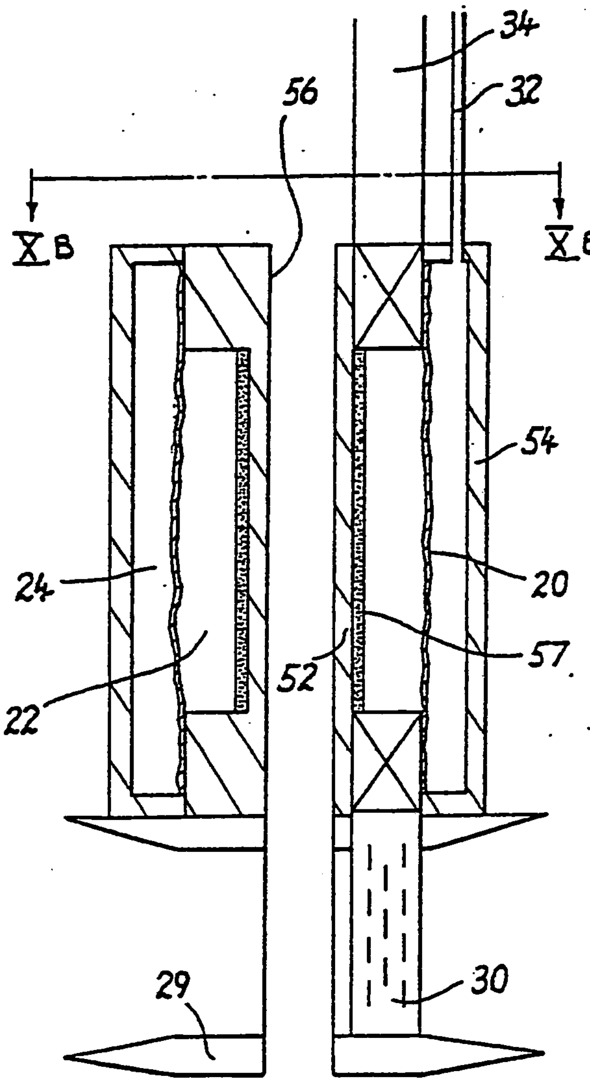

FIG. 10A

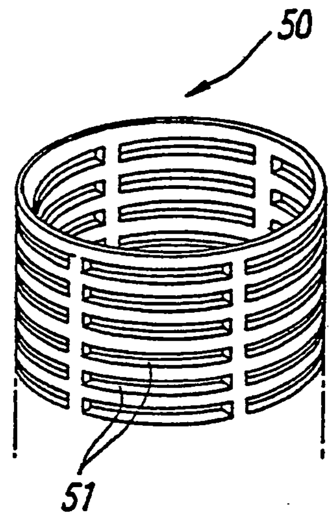

FIG. 9

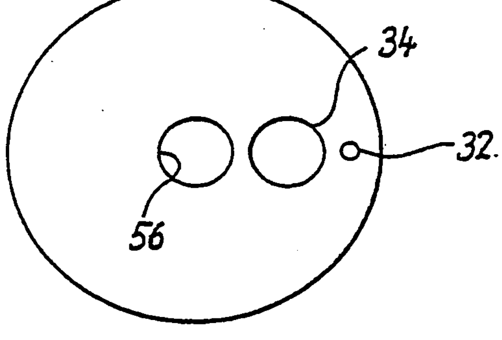

FIG. 10 B

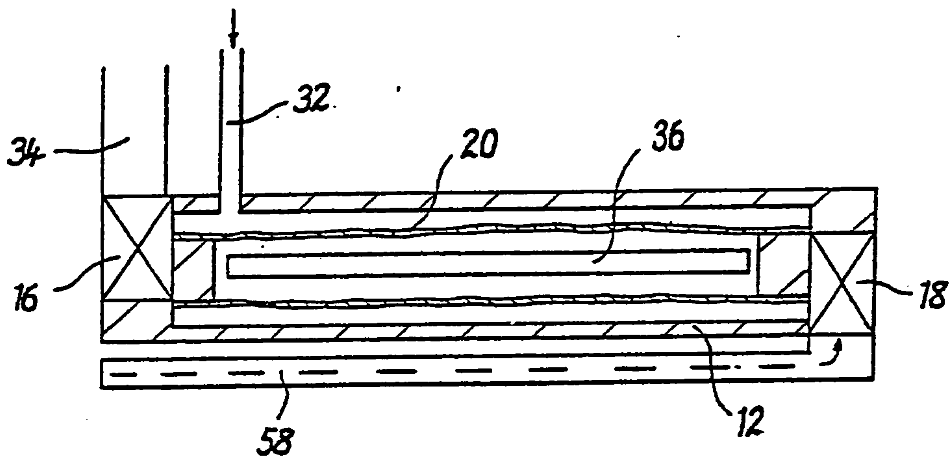

FIG. 11B

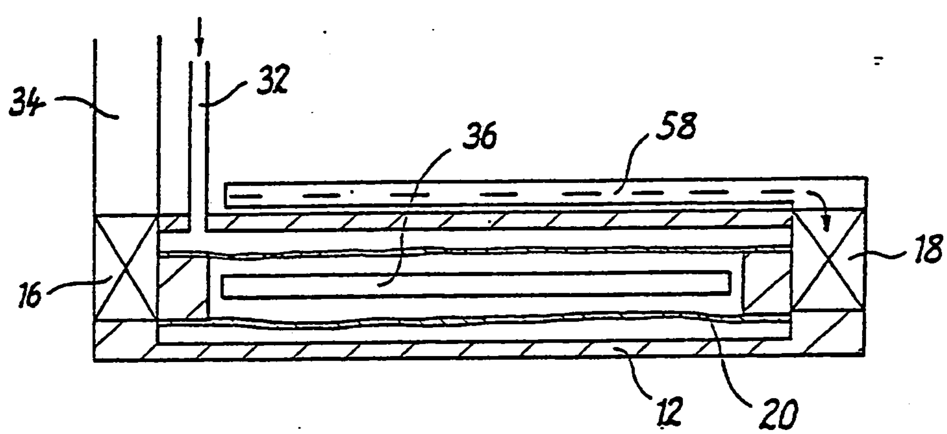

FIG. 11A

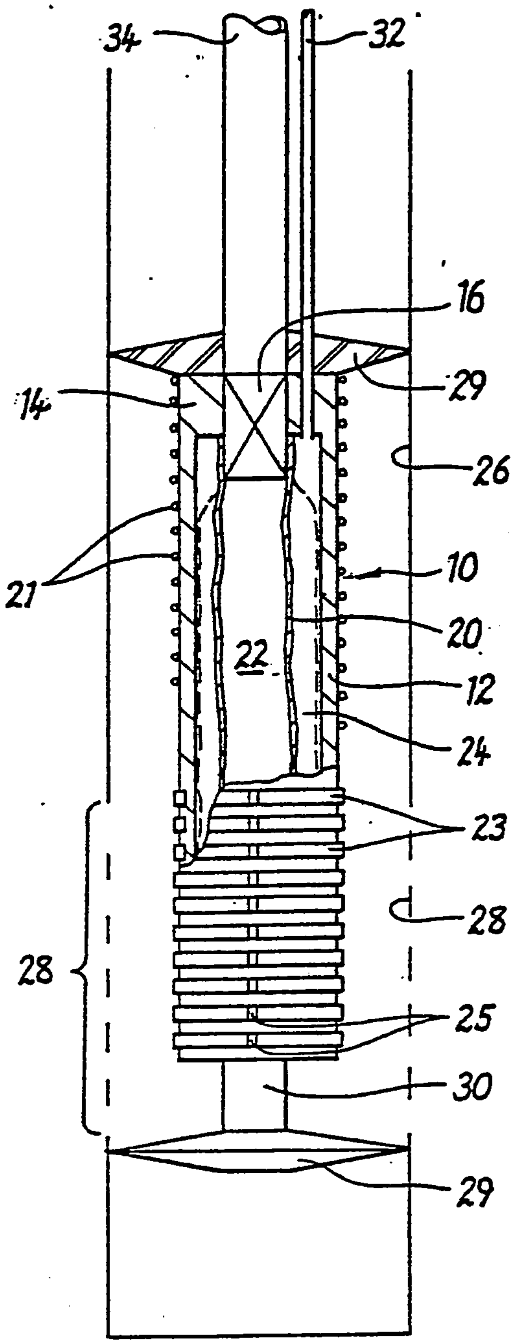
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FIG. 12

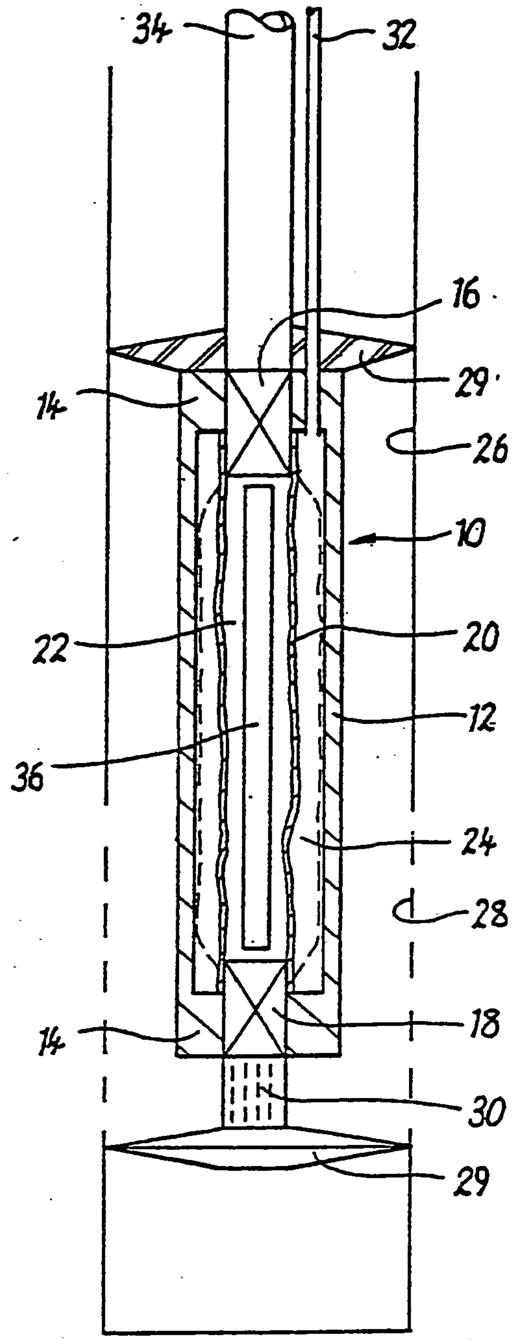
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FIG. 13

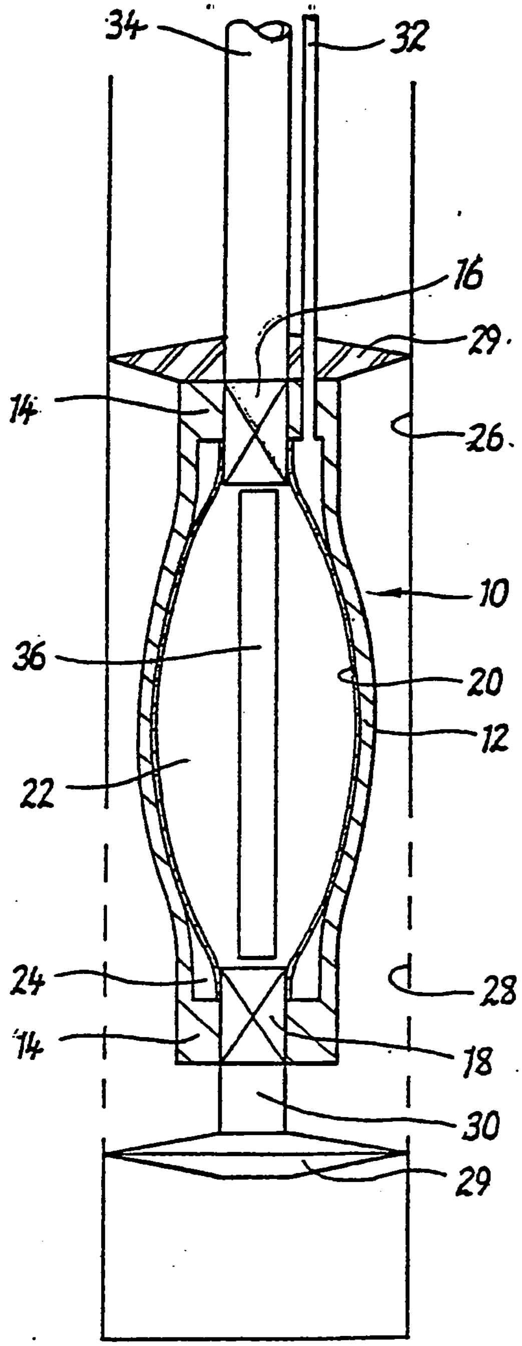

FIG. 14

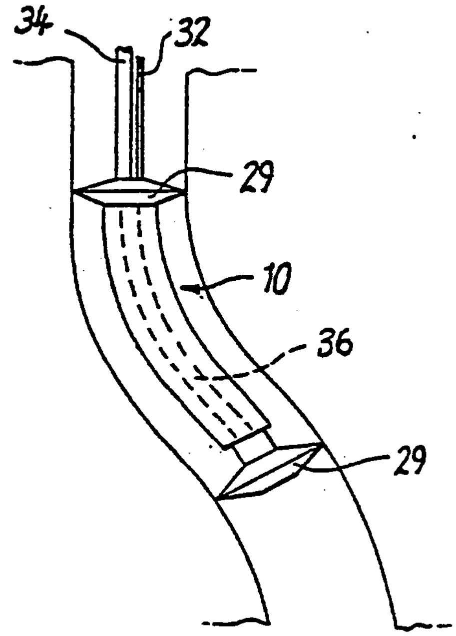

FIG. 15

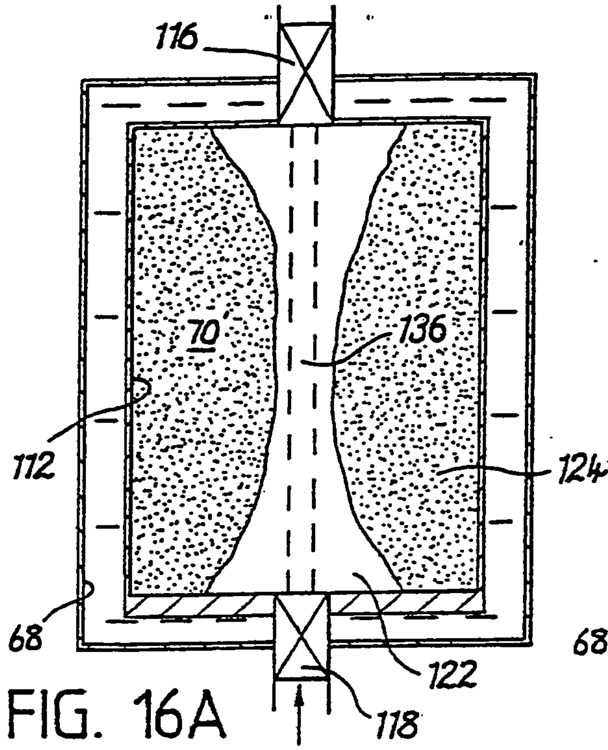

FIG. 16A

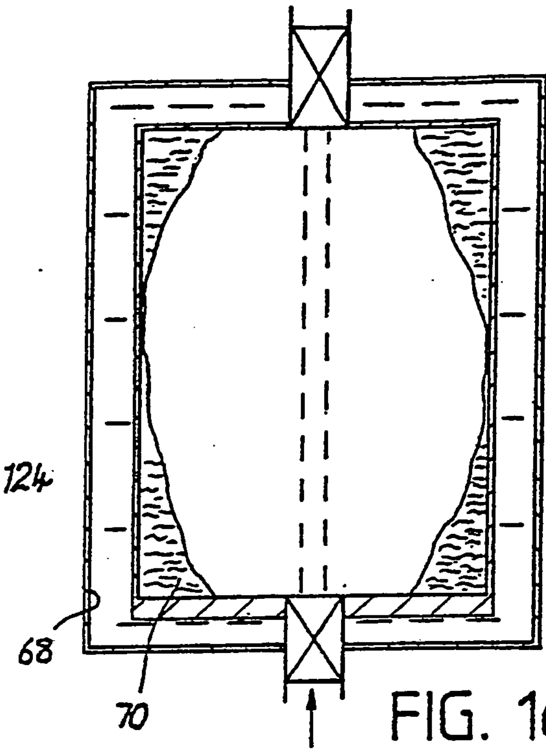

FIG. 16B

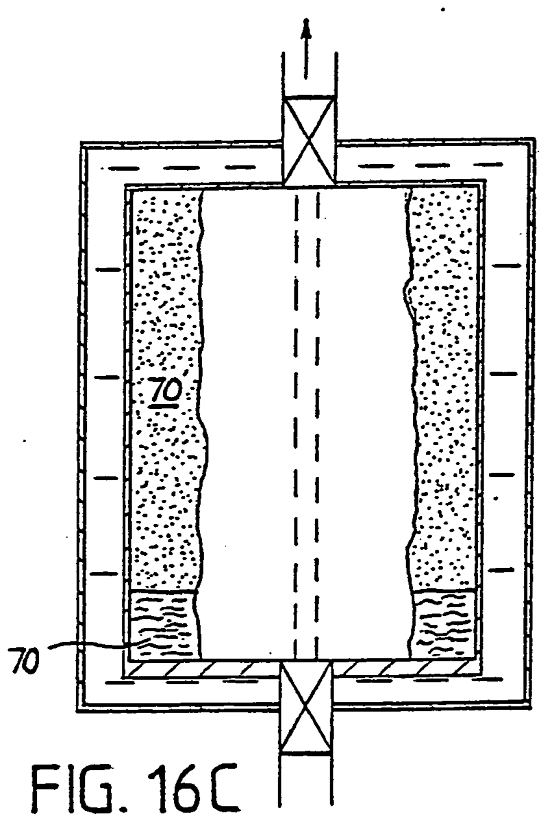

FIG. 16C

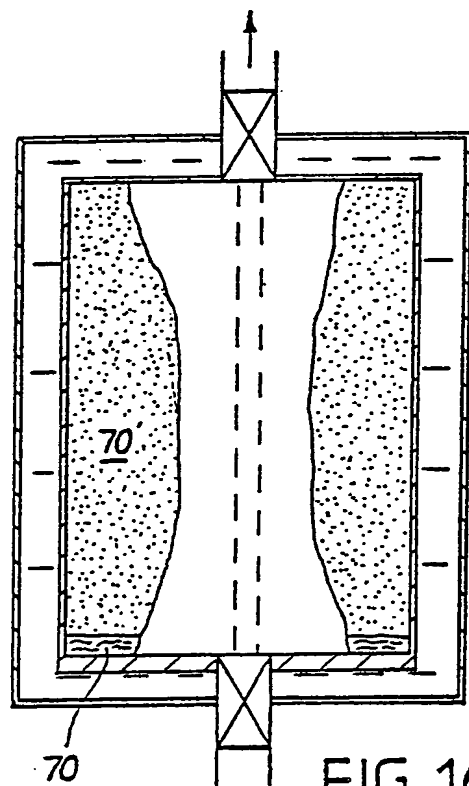

FIG. 16D

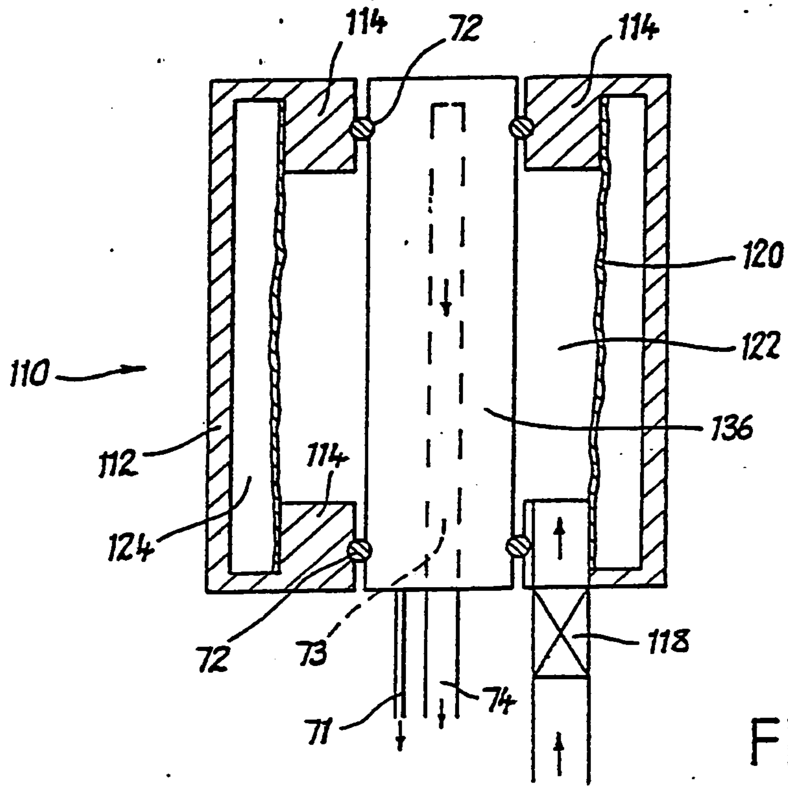
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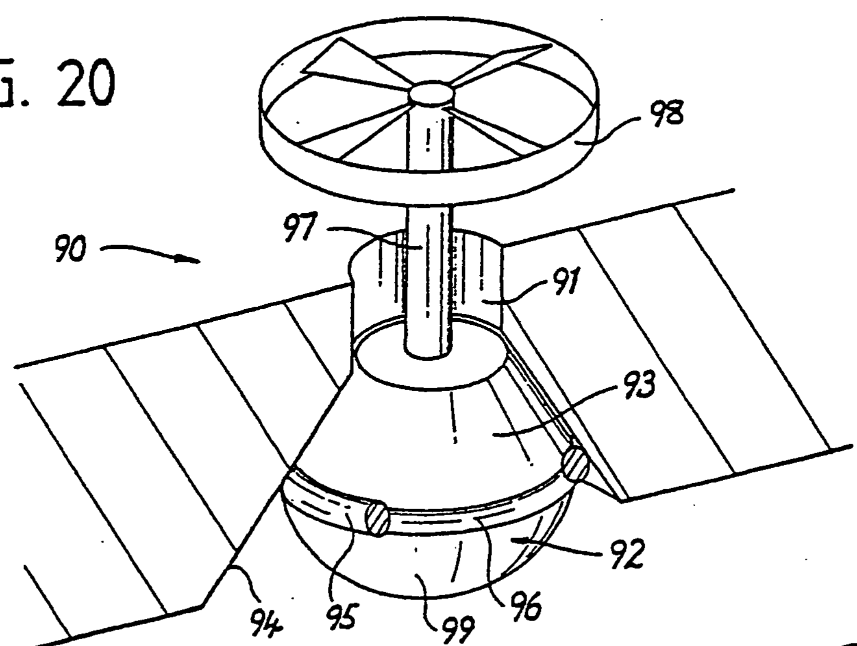
FIG. 17

FIG. 20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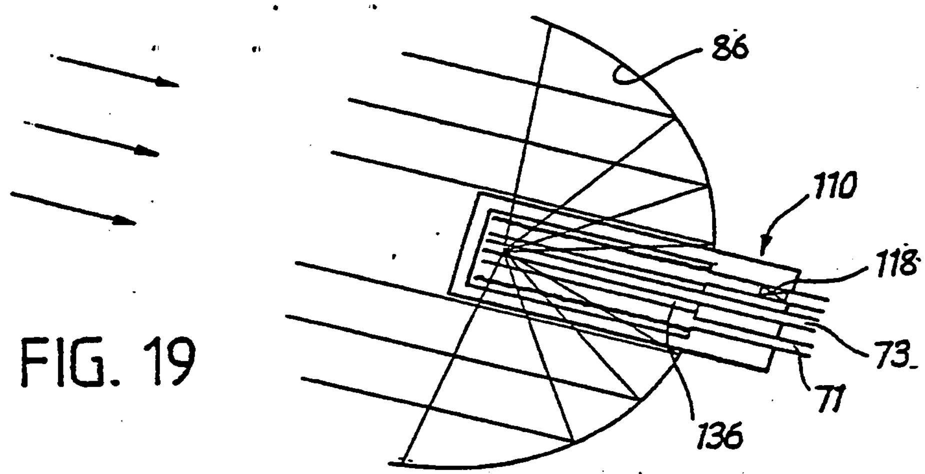

FIG. 19

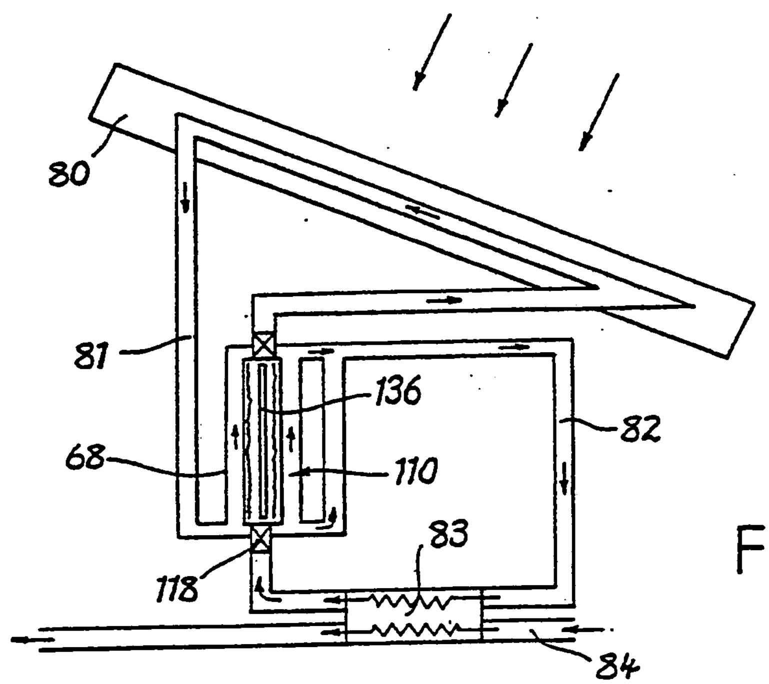

FIG. 18

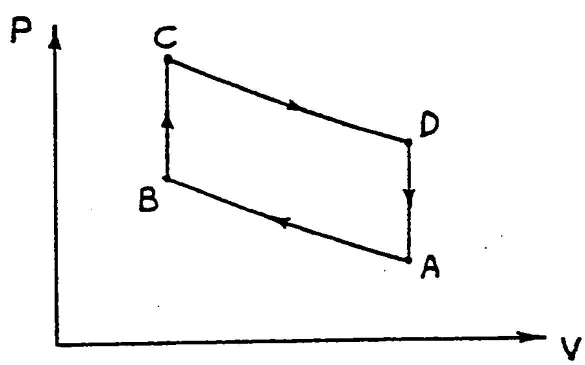

FIG. 16E

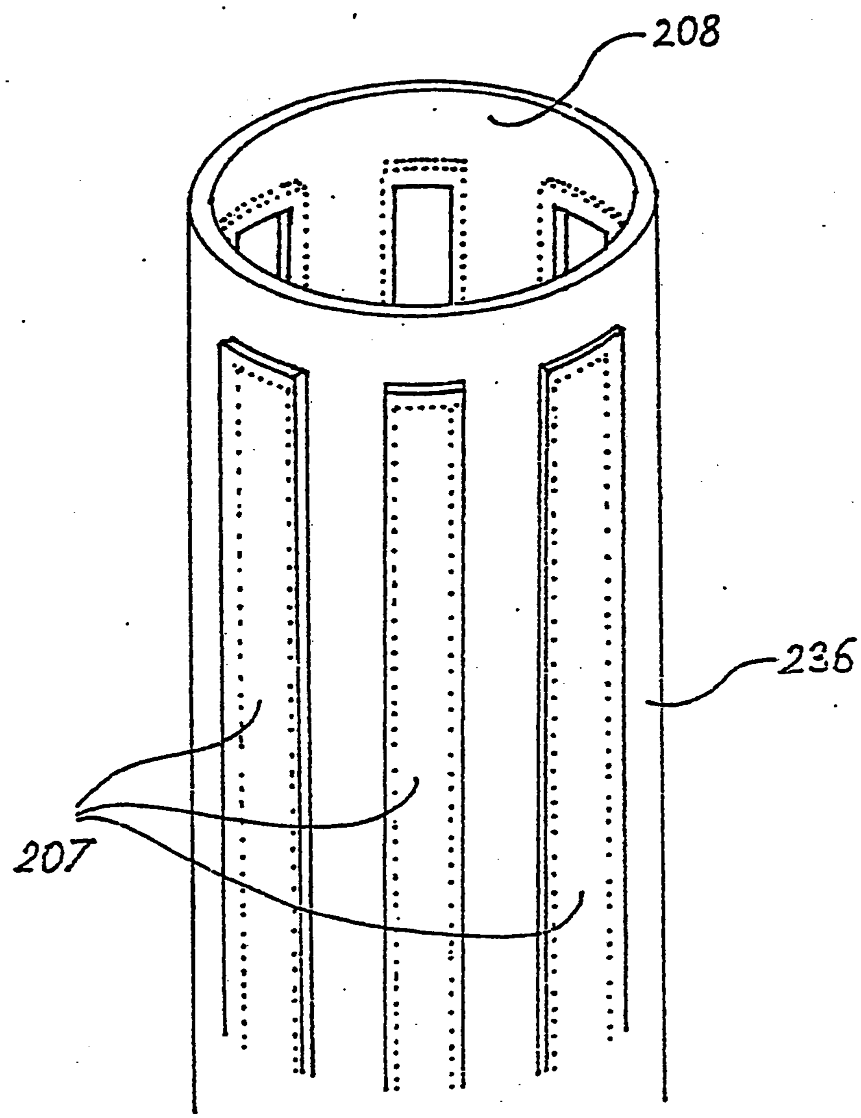

FIG. 10E

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 81/00165

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[3] E21B 49/08, F04B 43/10

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC US.Cl.	E21B 49/08, 49/00; F04B 43/10 417/478

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

AU: IPC as above; Australian Classification 68.3

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X,A	US, A, 3062153 (LOSEY) 6 November 1962 (06.11.62)	(1-6,15)
P,A	US, A, 4257751 (KOFAHL) 24 March 1981 (24.03.81)	
X,A	US, A, 3253549 (VINCENT, et al) 31 May 1966 (31.05.66)	(1-4,15)
A,X	US, A, 2971465 (CAILLAUD) 14 May 1961 (14.05.61)	(1-4,15)
A	GB, A, 1400150 (HART) 16 July 1975 (16.07.75)	
A	GB, A, 1347792 (TECNA CORPORATION) 27 February 1974 (27.02.74)	

* Special categories of cited documents: [15]

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
11 February 1982 (11.02.82)	16 February 1982 (16-02-82)
International Searching Authority [1]	**Signature of Authorized Officer [10]**
Australian Patent Office	R.J. Sawyer

Form PCT/ISA/210 (second sheet) (October 1981)

BAD ORIGINAL